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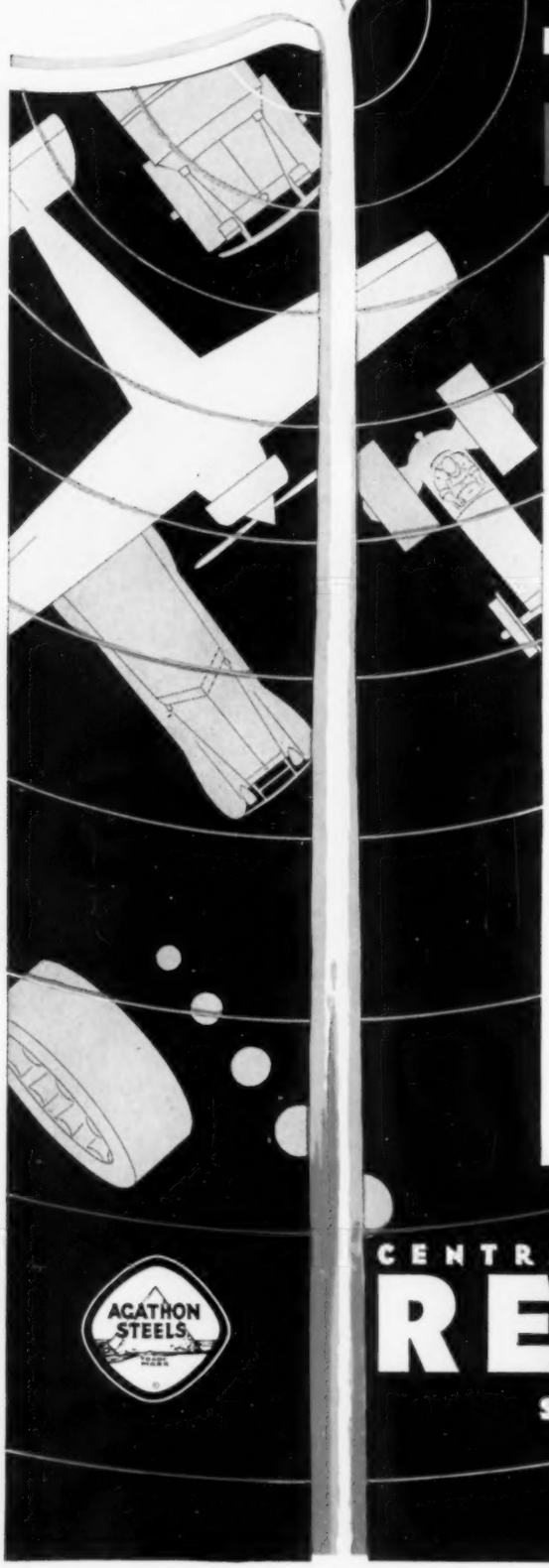
METAL PROGRESS

AUGUST 1932

SOMEONE MUST BE THE LEADER..

IN FINE STEELS IT'S

REPUBLIC



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STEEL CORPORATION

Massillon, Ohio

August, 1932
Volume 22, No. 2

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Ernest E. Thum, Editor

Metal Progress

table of contents

CHEMISTRY 20

MICROSCOPE 21

STABILITY OF STEEL 30

SERVICE TESTS 35

GRAY IRON 38

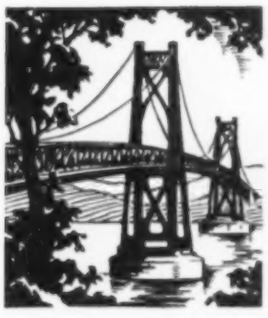
DRY POLISHING 39

PROFITABLE RESEARCH 41

CORRESPONDENCE 46

CONCENTRATES 54

Authors . . . . . 12 Advertisers 64



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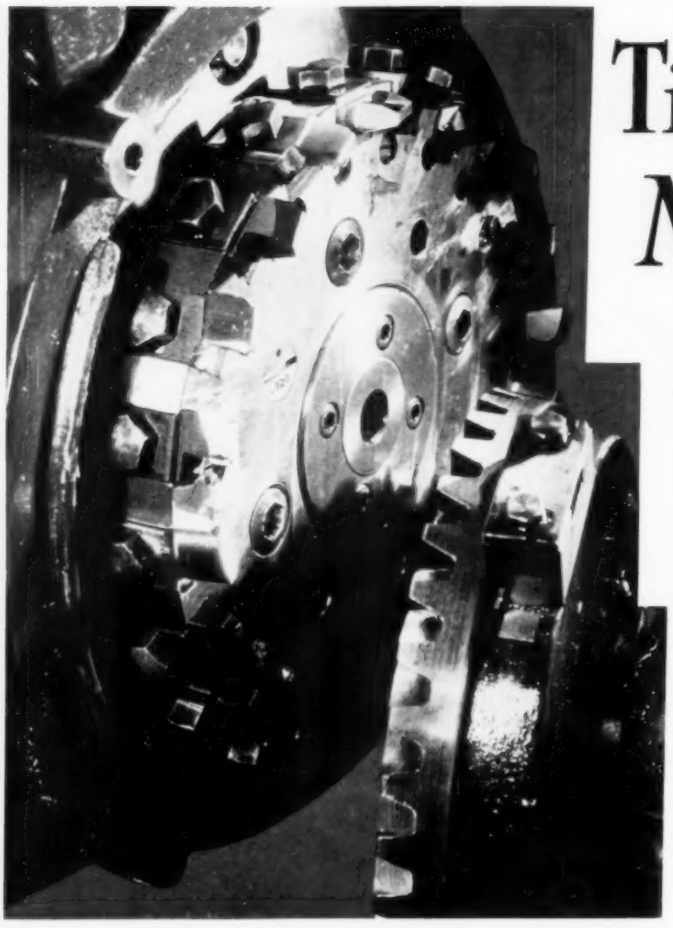

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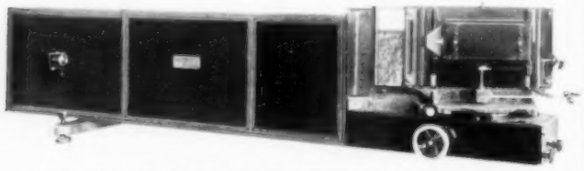

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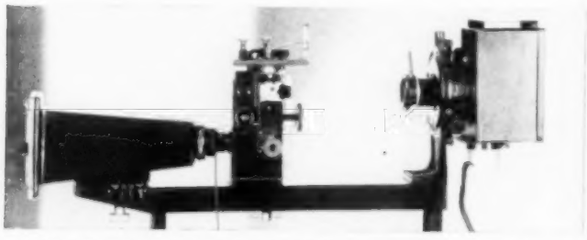

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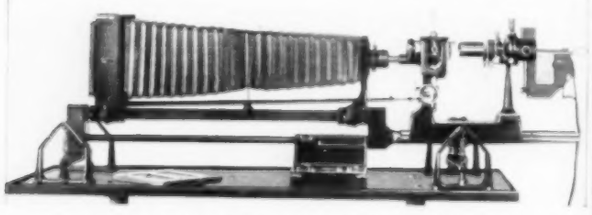

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In this issue

S. F. Urban

R. Schneidewind

J. L. McCloud

The photomicrographs on the cover are from the series which ROY M. ALLEN, consulting metallurgist, Bloomfield, N. J., has presented to a number of chapters of the Society.

The description of the new type microscope which is the leading article this month was written by L. A. DANSE, chief metallurgist of the Cadillac Motor Car Co. It follows closely Mr. Danse's recent talks to A.S.S.T. chapters.

J. L. MCCLOUD on page 35 describes some of the service tests used at Ford Motor Co. Mr. McCloud, a graduate of the University of Michigan, has been with Ford for 17 years. When the tractor division operated as Henry Ford & Son, he had charge of chemical and metallurgical work. Since then he has directed this department in the Engineering Laboratory of Ford Motor Co.

The story of dry polishing of metallographic specimens is told on page 39 by STEPHEN F. URBAN and RICHARD SCHNEIDEWIND, both of whom are in the Department of Engineering Research at the University of Michigan.

E. E. THUM, editor of METAL PROGRESS, on page 30 continues his articles on the causes of failure in the wire used in the Mt. Hope and Ambassador bridges. In collecting his data, he sought wherever possible the prime source of information about the subject.

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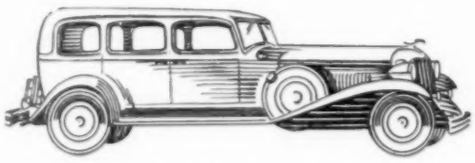

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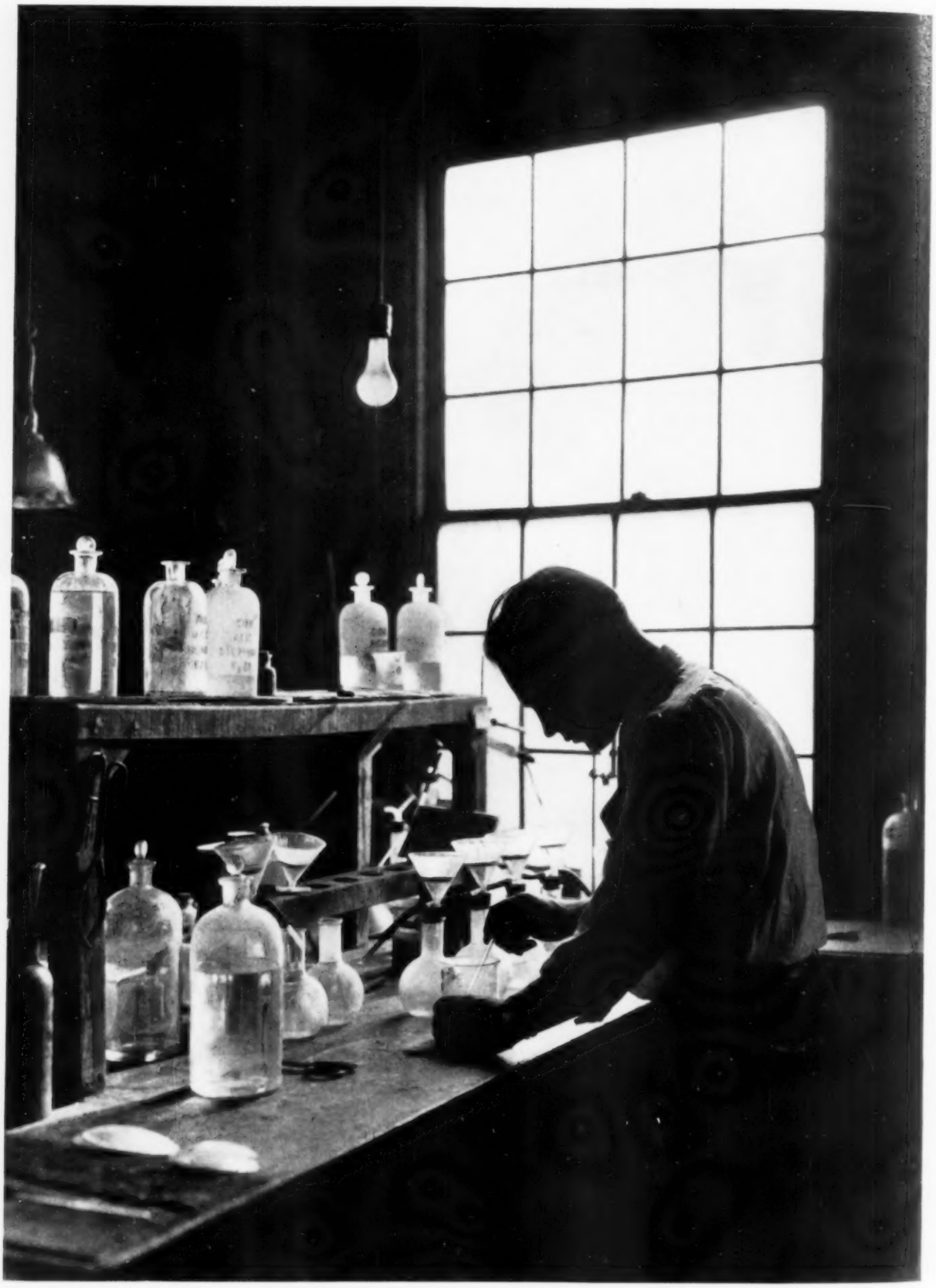


A Corrosion Test

Photo by John P. Mudd for The Midvale Co.

A Contribution from
the Metallurgical Dept.
Cadillac Motor Car Co.

New microscope designed for production

SUPPOSE you dreamed about a new car; about this wise: An attractive advertisement draws your attention. "The Snortenrattle Seven is an entirely new design. Every part and every assembly has been completely worked over along the latest lines of development."

So you and the madam look up the dealer's establishment and find a palatial salon, a salesman who is Beau Brummel up to date, and a car which is an elegant ensemble of wonderful color, luster, and line. The result is that you are completely captivated.

Next day you are in a glow of anticipation, which climaxes when the new creation is parked before your residence. The family is agog and the neighbors also look on with evident interest. Forthwith it is decided to call on friends in a neighboring city and you prepare to start.

Getting in, you bark your shin on the control lever — excited. Madam tears her coat on the inside door handle, but she too must be excited. (That door handle is such a beautiful design!) You reach for the starter button, but there is no immediate response so you pump the throttle just as — too bad, you pinched your finger in the throttle control.

Settling back in the seat as the engine purrs sweetly, you release the emergency brake, skinning a knuckle on the instrument board. Not so nice! Engaging the gears, you scuff your shoe on the pedal and find that your elbow strikes the seat-back cushion when you shift. So you disengage the gears and move the seat back to clear your elbow, to find that the steering wheel is too far from you. Well!

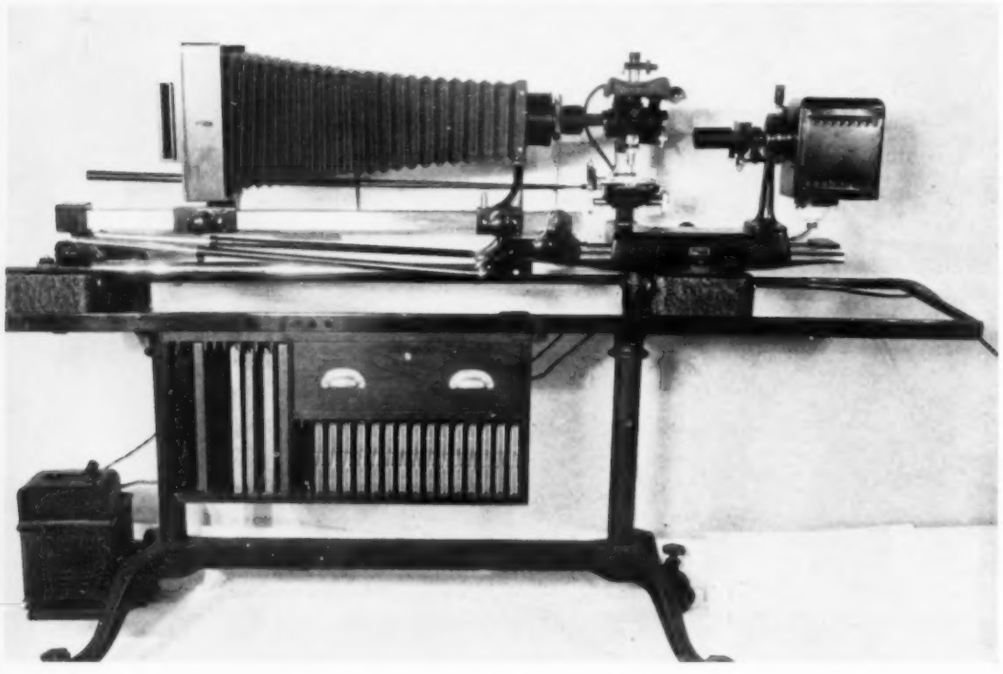
Moving off, you shift from first, but just miss getting into second — the seat is too far back. So you try again, leaning over the wheel and shoving the lever into second — also denting the new hat, which slips off due to the effort you are undergoing. Anyhow, you got into second!

At the corner, turning into the avenue, you tear your coat cuff on the window regulator handle (also an artistic, graceful design), which seems to run up your sleeve as you turn the steering wheel hard over. Such luck! You shift into high, hitting Doris's knee with the lever as you shift. She whimpers but you remark, "Well, Doris, keep over away from the controls."

Wheeling out on the avenue ("Doesn't this car run smoothly?") you again become enthused — until you hit the high car track at Sixteenth Street! Then you finish the dented derby against the top, putting it down around your ears. You hear a choked protest from madam and jam on the brakes, only to hear Doris start

crying. You have put her up against the windshield and her nose is bloody. Attempting to assist her, you ruefully realize that this is a nightmare, not a dream! You wake with a jerk to sad facts:

Not only appearance and sales arguments, but convenience, ease of control and performance are prime features in any machine, and a microscope is, primarily, a machine. It should be controlled and manipulated easily and conveniently, the controls should be comfortable of access, and the equipment should perform satisfactorily and rapidly for the purpose intended.



Yet how many correspond in detail to the Snortenrattle Seven of your dream? How few are really designed first and foremost for accuracy and convenience of manipulation?

About ten years ago, one of the Cadillac Motor Car Co. metallographers began to have eye trouble, so it was decided to procure a binocular eyepiece equipment. But no, it wasn't made — particularly not for a metallographic microscope! Why, nobody would want it. It wouldn't be practical. But here was a good microscopist losing his sight due to eye strain. So we asked the makers if they would do it or if we should. After much argument, they decided to fix us up.

The next step was to get greater adjustments on the stage and a stage that would not drop the specimen through the hole. So a solid stainless steel stage was built.

Then it was desired to make the setup more easily adjustable. The first step was to combine the illuminant and the condenser into one unit which would be pre-aligned and would only require the beam of light to be focused and centered in the vertical illuminator. This brought on more argument. It wasn't done. It couldn't be done. It wouldn't work. It was impractical. It was, to say the least, crazy.

But we wanted it and we could see no reason why it shouldn't be done. If it could, it would be a great convenience indeed.

So, upon our threatening to do it ourselves, it was finally agreed to build an illuminating system with the lamp housing and condenser combined into a single unit.

Thus was built the first metallographic microscope with the illuminating system built as a unit with the viewing system. As a result of this work at Cadillac, the type of metallographic microscope having an integral illuminator, pre-aligned, was put on the market. Before this time, there was a lamp housing on one stand, a condenser on another, and a microscope on a third. Often, also, a cooling cell on a fourth. Then the puzzle was to get all these many items aligned. Each could be raised, lowered, and turned. A smart man, who worked fast, might get the whole setup in line in half a day. Now it is a few seconds or, at most, a few minutes.

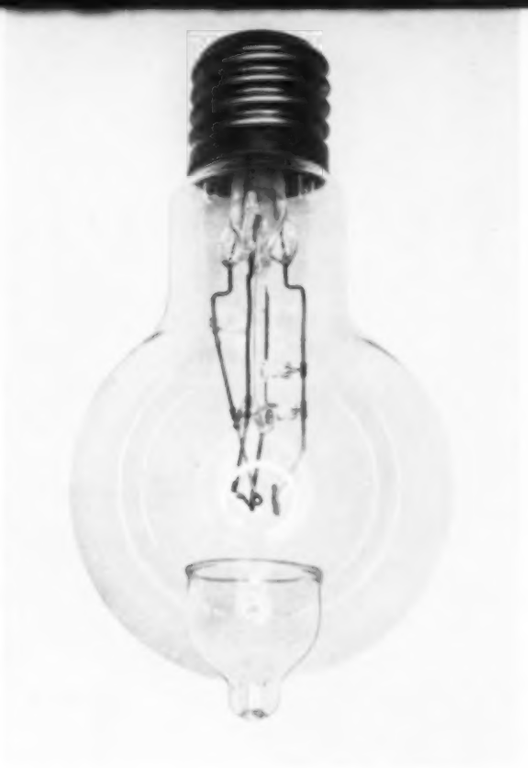
It was desired to try the English Ediswan "Point-O-Lite" as a source of illumination. It proved satisfactory. The bulbs are expensive, but economical over a period of time. And they are an absolutely steady and uniform source of light for metallographic microscopy.

Time passed. Various optical benches, both normal or straight-up and inverted or up-

side-down, were tried; four imported and three domestic makes. All were found wanting in some particular. The most noticeable feature was the fatigue they caused. With good nerves and a strong constitution, one could work steadily for perhaps three hours, but here we were with work enough to keep a metallographer busy all the time!

More time passed. Then came the day when it seemed advisable to purchase additional equipment. An estimate was prepared on the outfit needed and then the whole situation was explained to the Works Manager. The ideas gathered over a number of years, from scores of metallurgists and metallographers, were detailed to him. And he, being wise in the ways of the world, and a technical man as well as an executive, decided in favor of a new design, to be premised on speed and convenience of accurate manipulation.

In other words, we at Cadillac were not satisfied to take an optical system and drape some metal around it and call it a metallographic microscope. Nor were we willing to try equipment which might serve the college or research scientist, to whom time is of little moment. What was required was speed; a microscope designed to be as fast in metallography as the modern production machines and tools are in the factory — in short, capable of turning out more work in less time.



500 C.P. Point-O-Lite Bulb

Illuminating Unit Has Lamp House to Right; With Vertical and Horizontal Centering Adjustments to Stand. Condenser focusing handle to left of stand. Iris diaphragm and conical illuminating adjustment next to left. Water cell, color filter ledge and light tunnel to left.

As can be seen from the view of the complete bench and equipment, page 22, the microscope's optical axis is directly over the right leg of the stand, so that the operator can sit with one knee on each side in comfort.

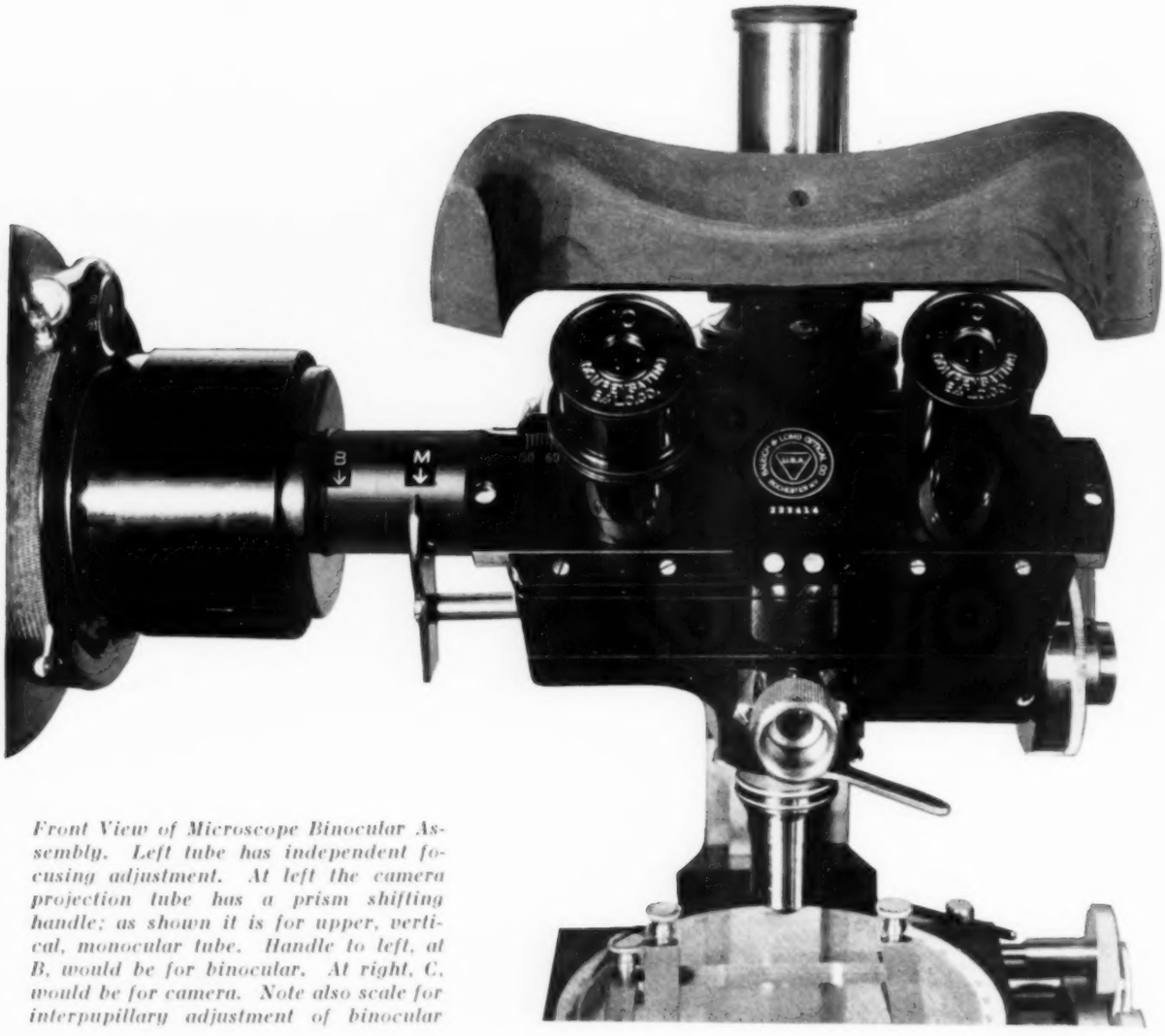
The position of the oculars is adjusted so the operator sits naturally, without strain. To increase comfort, a head rest is provided over the oculars. Sitting in comfort, with the weight of the head partially supported by the head rest, relieves the neck of most of the strain generally resulting from sustained microscopy.

Further to promote ease and comfort, the stage and focusing controls are so located that the arms and wrists can be rested on the frame. No fatigue is engendered by holding arms and hands out in mid-air, as is customary with other metallographic equipment. Coarse focusing and stage plate motions are controlled by the right hand, while the left is free to manipulate the fine focusing, as shown in detailed pictures on page 29.

Note particularly that the frame of the microscope is at the rear, leaving the front open and unobstructed for manipulation or observation of specimen, lenses, and stage.

Low type vibration and shock absorbers are provided to make operation comfortable.

An accessible drawer is provided in the cab-



Front View of Microscope Binocular Assembly. Left tube has independent focusing adjustment. At left the camera projection tube has a prism shifting handle; as shown it is for upper, vertical, monocular tube. Handle to left, at B, would be for binocular. At right, C, would be for camera. Note also scale for interpupillary adjustment of binocular

inet under the stand, to hold lenses and other attachments at the operator's finger tips. The table top is handy for note paper at the right hand.

Switch and resistance for the illuminator are at the left, so the heat liberated will not bother the operator.

The illuminator is equipped with several lamp units: 500 and 100 candle power Point-O-Lite, Mazda lamp, and automatic feed arc.

The 500 candle power Point-O-Lite shown on page 23 is in regular use. It operates from d.c. lines through the special starting box on the floor. Throwing the switch handle all the way to the left lights the filament and ionizes the gas in the lamp. Placing the handle halfway to the right strikes an arc from the filament to the ball. When it is all the way to the right it lights the running arc, from the ball to the target. This heats the target to incandescence, and the white-hot target is the source of light which is focused by the condenser into a parallel beam.

The lower photograph on the preceding page shows the iris diaphragm on the conical illuminator slide, equipped with click notches and spring to register the iris adjustment in given positions. This is similar to the click device which shows when the conical illuminator slide is in the center position. The operator is thus relieved of the necessity of watching closely; he simply pushes it over, click, click, click, to the third notch, by feeling and sound, and he gets an exact adjustment almost instantly with no effort.

The customary water cooling cell is provided, as is a ledge for color filters and a light tunnel.

This entire illuminator unit is mounted on an extra heavy sliding base, integral with the microscope stand and fastened to the ways by a handwheel clamp screw.

The vertical illuminator in the microscope has an auxiliary iris, also fitted with click notches and spring, and a swinging window

frame carrying a green Wratten B filter. This is the filter most used and is fitted so it can be quickly swung over the opening, as shown in the figure below, or back out of the way.

A polarizer is also available, which can be placed in the opening in the vertical illuminator and registered, by means of click notches and spring, with an arm which reaches over the head of the vertical illuminator. There are three positions wherein the polarizer can be registered. When neither the filter nor polarizer is in use, dust is excluded by a plane glass window which seats in the polarizer recess.

The vertical illuminator is provided with both prism and plane glass reflectors, either of which may be positioned by a touch of the knurled head of the mounting cell.

Binocular eyepieces shown opposite are not an attachment, but are built into the body of the microscope, and set at an angle for comfortable observation. The interpupillary distance is adjustable, this being a graduated adjustment, and the left eyepiece can be independently focused. To facilitate cleaning, the eyepieces, slides, and prisms are built as a sub-assembly, quickly detachable by backing out two small screws.

The head rest over the oculars is taken from a naval range finder. (If the gob who operates a range finder on a battleship needs to be comfortable, why shouldn't a metallographer?) The head rest is adjustable to suit the head contour of the operator, and the adjusting slide is graduated, so it can be quickly reset after being changed.

In the body of the microscope is arranged a prism slide, operated by a handle convenient to the left hand, below the side tube to the camera. When this handle is located at B (by a stop and a click spring) the prism assembly directs the light from the objective up into the binocular eyepieces. Sliding the handle to click at M, light from the objective passes through an opening in the prism assembly directly to the vertical monocular eyepiece.

Placing the prism slide handle clear over to the right against a stop at C (hid behind the binocular housing) brings the light from the objective to the left side tube, and, with its projection eyepiece, to the camera.

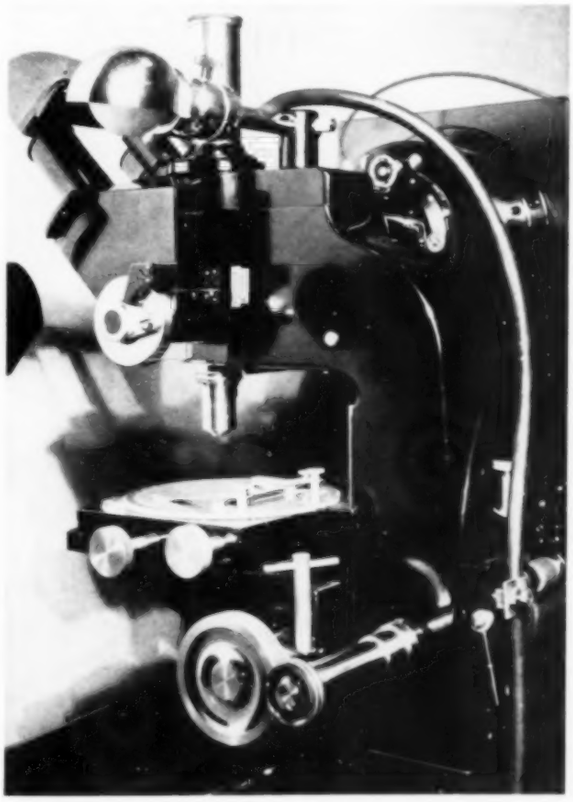
The objectives are fitted with the customary handle and quick changing mounting.

Three compensating oculars of each power are provided, matched for interchangeable use in the side tube, binocular, or monocular.

It is convenient and fast, where a considerable amount of micrography is done on routine examination, to keep the eyepieces and camera fitted for work at 100 diameters, and to keep the filar micrometer eyepiece in the vertical monocular tube.

Since a great deal of steel is examined at Cadillac for cleanliness and crystal size, general examination of the whole area of the specimen is done with the binocular. Sizes of inclusions are readily measured by merely switching the light to the filar monocular. The average or extreme inclusions or micro crystals are photographed by sliding the prism assembly to C and operating the camera.

Microscope From Right Rear. Wratten "B" filter in window swung over vertical illuminator opening. Fine focusing adjustment set to center, on graduated scale. Reading lamp swung to right to read centering scale, fine focus thimble and vertical illuminator iris diaphragm



A micrograph of an inclusion, void, scratch, or crack can be taken through the filar eyepiece by sliding the microscope base to the right against a fixed stop, and bringing the camera axis in line with the vertical monocular axis, with the camera in the vertical position.

Coarse focusing, through a range of 1 in. up and down, to allow for extremes of specimen sizes, is by means of two large milled headed knobs, one on each side of the stage knee. (This stage slides up and down on the microscope frame, the latter being fixed to the base.) On the right hand side is a T-headed knob for clamping the coarse adjustment, as best shown in the figure below.

Fine focusing of the lens system is done with two milled head knobs, a large one to the left and a small one to the right. The small one is for the purpose of spinning the fine focus rapidly back to the center position, shown by the scale on the side of the frame.

Instead of starting an examination haphazard and then stopping, after hitting the end of the movement, to center up the fine focusing adjustment, it is much better first to spin the fine focus motion to the center graduation by means of the small knob.

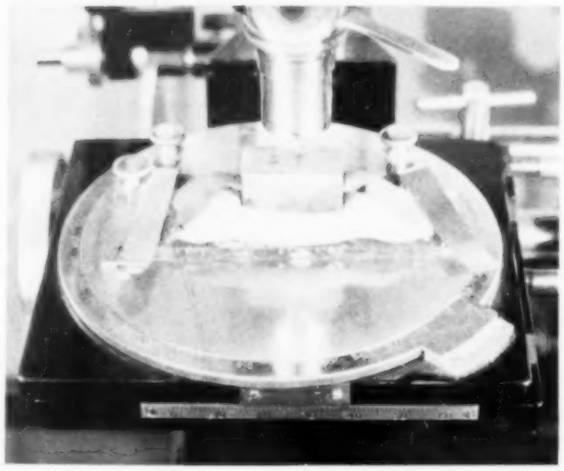
The Vertical Monocular with Filar Micrometer Eyepiece Is Fast. All examination may be done seated, with binocular, then the field selected quickly measured by shifting prism handle to M and standing to use filar. To photograph, microscope and illuminator base is slid to right against stop on bed and camera tipped to a vertical position

Another graduation is provided on the small knob for focusing, by means of the thimble against the frame, also shown in the view at the left. This indicates vertical motion of the objective and is useful for measuring the height or depth of micro-constituents. The thimble has 50 graduations, each of which indicates 2 microns. It is easy to interpolate to 1 micron, or even less. This makes a very convenient measuring device in conjunction with the graduated stage slides and rotary plate shown on next page.

A small electric light is fitted to a swinging arm on top of the frame to illuminate the various graduated slides and thimbles, for a microscope is usually not in a brightly lighted location. This lamp is shown more clearly in the photograph on page 25.

Three stage plate motions are provided. The ordinary fore-and-aft and right-and-left sliding motions have 60 mm. travel (instead of the customary 30

Specimen Is Mounted in Plasticene on Slide, Set Against Stops to Rear and Left and Held by Spring Fingers. When rotating stage is at zero, appearance of ranked inclusions may be at an angle to stage slide motions and filar graduations

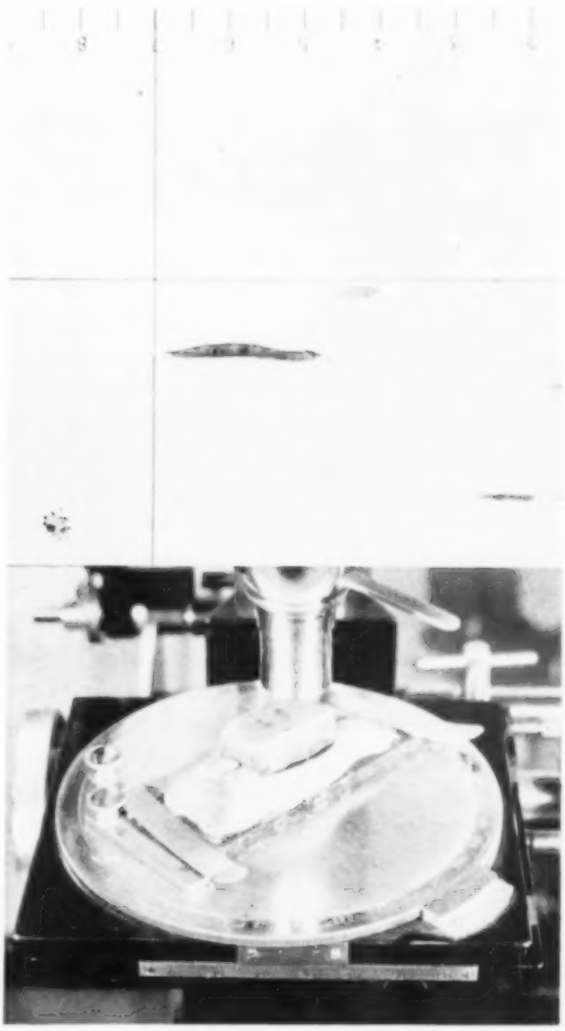


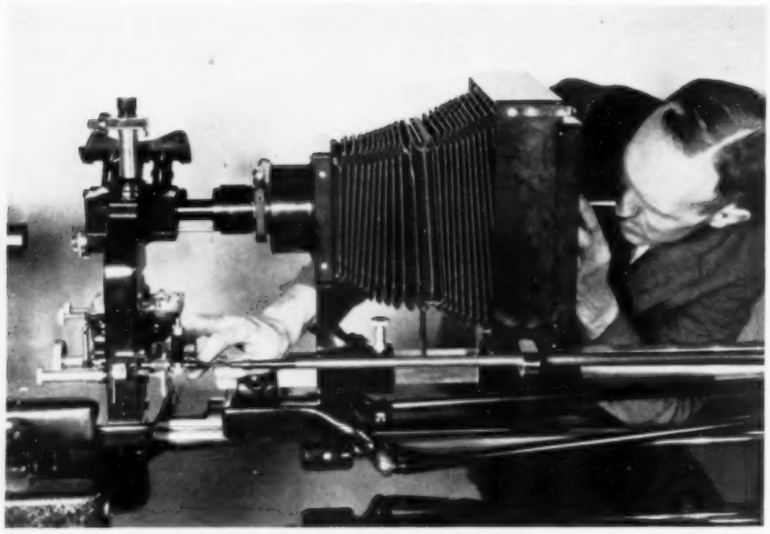
mm.) to facilitate examination of large specimens. In addition, the stage plate rotates through a complete circle graduated in degrees, with a vernier reading to 5 min.

While this whole microscope design is based on speed and convenience, the rotating stage plate is the handiest single feature. For instance: It is not always that the inclusions, or other special features to be examined, run exactly parallel to either of the stage slides when the specimen is first placed. With other microscopes it is necessary to turn the specimen by hand, or to "step" the stage motion in order to follow the line of the inclusion. This rotating stage plate may be turned until the inclusion is in line with the stage slide motion, when it may be followed throughout its whole extent.

In order to relocate speedily a particular area, a locating angle stop with spring fingers is fastened to the rotating stage plate. A specimen mounted upon its slide is pushed into contact with both arms of the locating angle, the area located, and the graduations of the two stage motions and the rotating plate noted. The specimen can then be laid aside and several others examined. The one first examined may later be replaced against the stop angle and the rotating plate, fore-and-aft slide and right-and-left slide placed at the original graduations — there is the area desired.

Rotating Stage Plate Turned to 315°, to Bring Ranks of Inclusions Parallel to Stage Slides so They Can Be Followed Across and Can Be Measured





Short Bellows Extension. Focusing direct with right hand on fine focus knob. Extension handle can also be used

The matter of mounting specimens on slides with plasticene is a moot question.

We have found it far more convenient and faster to mount on plates even for use with inverted microscopes. If the specimen is merely laid on the stage of these upside-down instruments, at least a third of the area is obscured by the stage. In traversing as close as possible to the edge of the obscured part of the surface, the lens often strikes the stage plate and tips it up. This may result in damage, or perhaps just in inconvenience.

The only practicable way to examine the whole area of a specimen with the inverted microscope is to use a mounting plate which will support it without using the V-shaped stage plate. But since the outfit is inverted, the specimen is also upside down and it does not always stay in plane with the stage. A far better way is to use a plain slide with the straight-up microscope; the specimen tends to stay of its own weight when mounted on top of the slide, even though the plasticene gets hot and soft.

A small press or fixture for mounting evenly and level, and a number of slides enable one to do the fastest, most convenient, and most accurate work. It is also possible to recheck a previously examined specimen with the greatest facility.

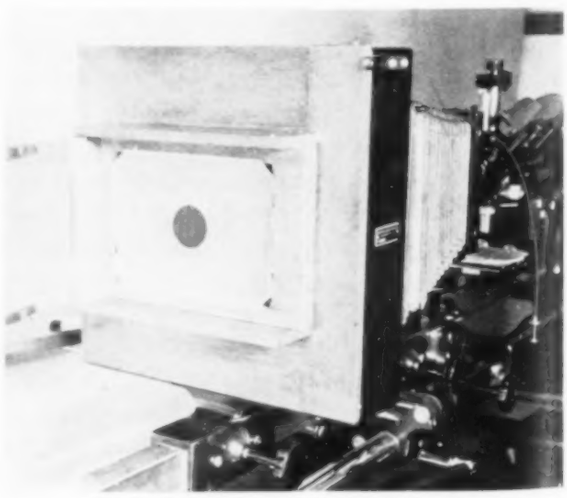
Metallic slides are preferable to glass, as the latter break and also wear the stage plate. Brass, electroplated with tin, is good, cheap, and easily procured. The tin plating should be thin and even, so that when it wears through, the brass will show and the operator will know that his slides are no longer flat. He can then re-surface and re-plate them.

The camera is a regular 8x10-in. camera as ordinarily furnished with metallographic microscopes. However, the front board stand is provided with a lock plunger. Two holes are drilled in the square slide; when the lock plunger drops in one hole, it locates the camera front properly for the horizontal position; the other hole locates it when vertical (page 26). Changing and setting up is easy and quick.

Only heaven knows why 8x10 cameras are put on microscopes! Nobody has any use for an 8x10 photomicrograph. Few even have use for a 5x7. Probably more 4x5 negatives are used than any other size, but most of these make smaller prints, often 2 or 3 in. square, for reports.

Since it is well nigh impossible to use smaller kits in an 8x10 plate holder, Cadillac long ago settled upon 5x7-in. plate holders. Some 5x7-in. plates or films are used. Satisfactory results attend the use of 4x5 kits in 5x7 holders, and over 95% of our work is with 4x5 plates (we use almost 2 gross a month). In order

Reducing Back for 5x7 Plate Holders



to facilitate work, we keep not less than 75 plate holders in circulation.

When the new equipment was designed, we insisted on a 5x7-in. camera back, to use plate holders of that size (of which we had several hundred in use). This reducing back was special and cost extra, but is a great convenience.

The complete comfort with which the operator can manipulate this equipment is distinctly shown in the last few illustrations.

In rapidly traversing the stage motions to return to a previously noted field on a specimen, the superiority of the open view of the specimen on the stage is particularly evident. Only a tilt of the head enables the operator to see, easily and fully, the specimen and the stage graduations. Instead of cramping the metallographer's style, owing to limitations of equipment hindering his fullest expression of his science and art, we enable him with this equipment to extend his possibilities far beyond what could be done with the old-style outfits.

With an Inverted Outfit, It Is Impossible to Dust Off a Specimen Without Removing It From the Stage and Entirely Losing the Position of the Field. This has to be done frequently and costs a lot of time and money. With this right-side-up outfit, it is easy to remove adherent dust or lint particles

Comfortable Working Position of Operator, Seated at Microscope. Index finger of left hand manipulates fine focusing adjustment. Right hand operates stage motions. Both arms rested. Head rested. Neck in easy, natural position. Whole body in natural, unstrained posture; which, with binocular vision, saves from fatigue

It has been suggested that the camera axis should have been raised or tilted in such a manner that the operator when focusing an image on the ground glass, should be standing full height. This was carefully considered, but decided that the expense of such a modification of the optical system ($1000 to $1200) was not warranted by the amount of work to be done. We also recognized that the intensity of illumination from an arc light is greater than from a Point-O-Lite, but on account of the latter's steadiness we get more work out of it in a day.

In developing this design, we were given criticisms, opinions, and suggestions by scores of metallurgists and microscopists over a period of years. To them we owe the fullest thanks for the many ideas which enabled the advance in design. To Bausch & Lomb Optical Co., which built the equipment, we particularly owe gratitude, as the arguments pro and con confirmed our convictions.

Is quenched and tempered steel unstable?

By Ernest E. Thum
Editor Metal Progress

A DESCRIPTION OF the manufacturing and erection procedure for the heat treated bridge wire first erected at the Mt. Hope and Detroit River bridges has been presented in METAL PROGRESS for June and July. It will be recalled that this material proved unsatisfactory and was promptly replaced, as soon as the defects developed, with the conventional cold drawn wire made of acid steel. In the articles mentioned reasons were advanced for the opinion that the heat treated wire was not abused during manufacture or erection and that the trouble was not due to the choice of basic steel or to variations from customary practices in the wire mill. The wire, after delivery and erection, was uniform, ductile, and strong, as proved by a tensile test on each length of wire before reeling.

With the hypotheses of unsatisfactory raw material and abuse during manufacture or erection ruled out, we face the fact that individual wires broke, and obviously were overstressed — more load fell on them than they could carry. But the bridge hadn't even been finished; the full dead load of the structure had not yet been imposed!

When the first broken wire was noticed at Mt. Hope, the computed average stress in the main cables was 32,000 lb. per sq.in. It will be remembered that the cables are laid up wire by wire, and the load on each wire adjusted by matching its center-span sag against the guide, in such a way that the variation, wire by wire, could be no more than plus or minus 1000 lb. per sq.in. That is to say, with a computed tensile load on the main cable of 32,000 lb. per sq.in., the individual wires were stressed somewhere between 31,000 and 33,000 lb. per sq.in. (average on the cross-section). It is therefore impossible that the wires which broke were overloaded in direct tension, for each wire in the preliminary testing had held nearly seven times that load before letting go.

Similar considerations rule out the supposition that the strands with the largest number of breaks were carrying more than their share of the stress.

It might be suggested that when the first break occurred (because of some fortuitous conjunction of circumstances) the redistribution of stress overloaded one of the other wires in the same strand, and it broke, overloading one of the remainder, and so on. But when the first wire let go, the others picked up, on the average, only 1/350th part of the direct stress they were already carrying — surely not enough to distress them if some of them were not on

the verge of fracture from other causes. Another fact that throws doubt upon this suggestion is that after a great many wires in one strand had broken, wholesale breakage started in another strand of another cable at the other end of the bridge, even though meanwhile the dead load on the bridge floor (and the tensile stress in the main cable) had been slightly reduced.

One glance at the broken ends of the wire indicates that the fracture is entirely different from the appearance of the same wire broken in a tensile testing machine. The illustration on this page, kindly loaned by the Bureau of Standards, shows a wire broken at Mt. Hope — there is little or no necking at the fracture. Apparently, it was very brittle. (One of the ends was tested in a tensile machine, however, and it gave a typical cupped break, with normal strength, elongation, and reduction of area, as shown in the same view.)

Square breaks, without reduction of area, suggest fatigue failure. Fatigue failures, as ordinarily meant by the term, occur under alternating, oscillating, or vibrating loads. For bridge wire this is ruled out of consideration because the loads on a suspension bridge cable during erection are quiescent, are solely due to the weight of the structure and erection equipment, which is gradually increasing, and at the time of failure amounted to one-sixth or one-seventh of the ultimate strength — far below the expected fatigue limit even though the loads had vibrated like an exhaust valve spring. Lacking definite tests on the steel we might assume that the endurance limit under alternating loads would be somewhere between 35 and 60% of the ultimate strength. As a matter of fact, the fatigue strength under alternating loads of this heat treated galvanized bridge wire has been determined by S. M. Shelton of the Bureau of Standards to be 50,000 lb. per sq.in. Passing over, for the moment, the reason for this unexpectedly low value, it may be here pointed out that even it is 60% higher than the unit load on the wire at its failure in the bridge.

All this is somewhat beside the point, however, for the type of alternating load responsible for the so-called fatigue failures did not exist in the bridge. The whole matter might more readily be dismissed with the observation that fatigue fractures have certain areas polished smooth where the surfaces of the incipient crack rub against each other, yet the broken wires in the bridge were free of these porcelanic areas.

So we will have to discard the hypothesis that the wires were overloaded by direct or vibrating stress.

But how about the compound stresses induced by bending the wires about the anchorage or clamping them under a suspender casting? This is a question which will bear minute investigation. Here it may be observed that if the trouble is in compound stresses, the failure should be ascribed to the nature of heat treated steel rather than to overloads. Many large American suspension bridges, with years of satisfactory service, were designed and erected with the same details at anchorages and suspenders. They differ from the first Mt. Hope and Ambassador bridges in the principal respect that the cables are spun of cold drawn wire.

In other words, the compound stresses which might cause trouble in heat treated wire actually do *not* cause breakage in cold drawn steel.

It should also be mentioned that many loops of the heat treated wire, one to ten ply, had

One of the Wires From Mt. Hope Bridge That Broke in Service With no Contraction of Area. One end was tested in tension at Bureau of Standards and broke with normal ductility. Natural size

been tested by the wire maker in order to determine the modulus of elasticity of the material. These loops were thrown about 17-in. sheaves, after "pre-forming" about a 6¾-in. sheave. Fractures on pulling to the limit in a tensile machine occurred at chance places along the straight wire (not on the curve or at the point of tangency) and at expected high strengths. (These tests have been duplicated by other experimenters, and the same results secured.) It may be concluded from these tests and from other considerations that the internal stresses introduced by bending a wire so it snugs up to the curvature of the anchorage shoe when it "lies dead" are small in intensity, and if there were any additions to the direct stresses at the bends, these increments were too small to influence the locus of the fracture in the tests mentioned above, or cause any observable distress in cold drawn wire.

Of course, the presence of a broken wire is clear evidence that it had been loaded beyond its strength, but we may dismiss the supposition that the load, whatever it was, either across the average area or at the highest loaded element, would have broken the heat treated wire if the wire had been as strong or as ductile or as generally good as the conventional cold drawn bridge wire.

Material is Inherently Unsuitable

From what has already been said it is logical to conclude that the wire failed not because of this or that variation from standard manufacturing practice, but because quenched and tempered eutectoid steel is a class of material unfortunately unsuitable for the purpose, and unsuitable for some reason which was present in every inch of every wire — that is to say, inherent in the wire as delivered. Further support of this conclusion rests upon the fact that the non-ductile fractures which testing engineers could not duplicate during manufacture were localized in the bridge at anchor shoes and at cable clamps. Accidental variations in quality, too rare to escape the routine tests, can by no stretch of the imagination be conceived as finding themselves, several hundred times, at these precise locations in the bridge. The trouble therefore was not accidental, sporadic, occurring too rarely to be found by routine tests. It is inherent in the wire as made.

This conclusion is not at variance with the recorded fact that at Mt. Hope some of the trouble was concentrated: 140 wires broken in one strand in one cable and 130 wires in one strand of the other cable at the other shore. This occurred for the same reason that every wire did not break simultaneously — namely, that exact uniformity is impossible. Another way of saying the same thing is that numerical values of the properties of a certain steel are distributed within limits according to a probability curve. Furthermore, the limits and most probable value are shifted up or down, heat by heat. Since bridge wire is separated, heat by heat, clear through to the site, the concentrated breakages noted above were in wire of two heats of steel which were below par in the critical quality (as yet unknown) which caused the trouble. The last sentence is in accord with the well-known metallurgical fact that many intangibles cooperate to make or mar quality in a heat of steel, and this quality persists throughout its life in its toughness and its response to heat treatment and manipulation. The summation of these qualities has been called "body," "timber," or "sensitivity," and these qualities vary *by heats.*

If we have overlooked nothing important we have got this far in our inquiry: That the trouble is inherent in quenched, tempered, and galvanized high carbon steel wire. Let us now ask, in an effort to discover the specific fault: "Did the wire break because the effects of heat treatment are not permanent?"

In the opinon of metallurgists, such a suggestion would be too silly for argument. So it might. But the writer was once told by a prominent bridge engineer and a specification writer of sorts that he could not be happy to see heat treated alloy steels put into bridges because he was not sure that the effects of heat treatment could endure — they might evaporate, as it were. This is rather an important point to bridge and construction engineers, because even though heat treated bridge wire may never again be used, heat treated eyebars have been used for tension members in several long-span bridges erected in recent years, and are actively being promoted. Furthermore, some varieties

of carbon and low alloy steel, subjected to controlled coolings (heat treated), are proving their worth in the hulls of merchantmen and naval vessels.

Mysterious failures of metal have frequently occurred in apparently sound metal. Metallurgists have investigated many of these occurrences and believe them to be due to corrosion and severe stress, either alone or together. This conclusion is reached so often that it is almost an article of faith with them — in case of failure look first for corrosion, severe stress, or alternating stress. Long-time service records of heat treated steel would be the most convincing evidence for doubters, but such records are absent because steel was first used as a structural metal sixty years ago.

Looking Through Port in Anchorage Masonry at Mt. Hope Bridge. Cable has been completely spun but strands are not yet compacted. Wide World photo

The Eads bridge across the Mississippi at St. Louis, built in 1874, is the first large structure in the United States to use steel — and it was a low chromium alloy steel at that! A recent examination of the steel arch members by consulting engineers employed by the owners showed the steel members to be in excellent shape, and as far as could be determined unchanged with time.

But 60 years is rather short, in the eyes of history, and may not be enough to show the effects of a very slow change. Some other evidence is present, however. Professor Honda and his associates have studied heat treated steel swords laid away in Japanese tombs 600, even 1200, years ago, and find they have not undergone any change (other than corrosion). In other words, the scleroscope hardness, the microstructure, the sharpness, and the durability are equal or superior to swords of similar nature made today. The inner structure (martensite) remains as martensite, even though physical chemists call martensite "metastable structure." If such metastable metallic structures change at atmospheric temperatures, martensite, which is the first stage in the change from unstable austenite to stable pearlite, should have shown some signs of doing so in 1200 years.

Coming to the bridge wire in question, it has already been shown that broken ends of defective wire, removed from the Mt. Hope anchorage, and tested in tension, showed strength and ductility equivalent to the routine acceptance tests, and curled without fracture into a close helix. The broken wire was still strong! If it had lost its strength, that loss was only temporary, or at a tiny spot — which seems unlikely.

"But," asks someone, "how about the aging phenomenon?" Evidence multiplies that many of our common materials change somewhat with age. Some of them, like duralumin and hardened lead, slowly increase in strength at room temperature; measurable changes do not cease for days. Low carbon, cold rolled steel sheet may be stamped or deep drawn successfully if it is done promptly after rolling, but frequently heats are encountered which crack badly in the stamping presses if the work is delayed a month. Freshly quenched high car-

bon steel is known to generate heat spontaneously for some hours. Is it not possible that the quenched and tempered wire has an unstable structure, and therefore underwent some inner change *after* it left the manufacturer's hands?

The metallographist would answer this question by examining the microstructure, and by studying routine tests or fabrication processes on samples of different ages. Some evidence of this sort is available for this wire. Unusually extensive work at the Bureau of Standards (as yet unpublished) indicates that the structure of the completed wire is predominatingly troostite, with some undissolved carbides as small round particles scattered about. Metallographists will recognize that troostite is a structure exceedingly difficult to examine; at the Bureau the work was carried to 2000 magnifications. In last year's report of the Director it was noted that this "did not reveal any characteristics to arouse suspicion, either in structure or properties."

In other words, the structure of the wire at the present time is good and is uniform. It is fair to presume it always has been.

The suggestion that a certain amount of brittle martensite may have remained in the wire, and is incapable of being differentiated clearly from the predominating troostite even at 2000 diameters, is untenable. Recently published magnetic and X-ray studies show that the martensite in freshly quenched high carbon steel of this analysis is completely tempered at 600° F. — considerably below the heat of the lead tempering pot and the zinc galvanizing pots (about 800 and 850° F. respectively). Transfer of heat from such metal baths to a relatively small wire is very quick, and undoubtedly penetrated to the center.

Wire Tests OK Now

A better answer to the idea that there might have been progressive deterioration in the quenched and tempered bridge wire is in the statement that physical tests being made today, four years after it was produced, show that it is a first-class wire. For instance, a number of lengths of the wire have been coiled, 19 in. diameter, at temperatures ranging from 20 to 80° F., and the coils warmed and refrigerated on alternate days without any fractures occurring. Sharp bends may be made on cold wire. It is not brittle. Tension tests made at ordinary testing machine *(Continued on p. 62)*

Photograph of Mt. Hope Bridge by Fairchild Aerial Surveys, Courtesy McClintic-Marshall Co., the Builders

By J. L. McCloud
Ford Motor Co.
Dearborn, Mich.

A talk delivered at a joint session held at Detroit of the A. S. S. T., the S. A. E., and the A. S. T. M.

Laboratory investigations are secondary to service tests

IF WE WERE to be readily overawed by what we read, the following statement in the *Metallurgist*, January, 1932, would do so: "One of the greatest difficulties which faces the investigator in applied metallurgy is the reproduction in the laboratory of the conditions prevailing in the practical service of the materials with which he has to deal." Perhaps it is this very fact that has brought service testing into its prominence.

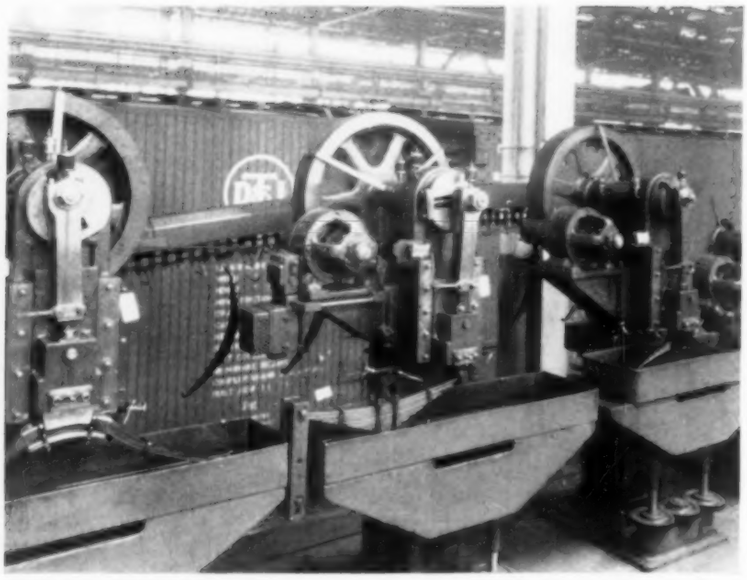
When a design or mechanism is composed of many elements, each of which has to be weighed in consideration to its effect on the life of the complete device, then actual operation is not merely the best way to test it but the only way in which reliable information can be obtained. There is, however, one disadvantage in this, namely, the time necessary to run such tests, since the useful life of the machine being tested must necessarily be enormously greater than the duration of the test.

Since most machines fail in service by wear or by "fatigue," the obvious way to perform a service test is to shorten the life or wear duration of the machine by overloading it. Overload may again be of two types, (*a*) merely increasing the dead weight or the stresses carried by the individual parts, or (*b*) by running the machine at higher speed or frequency than usual. Eventual failure may be by fatigue, in which the failure is progressive, or it may be by impact, in which failure occurs in one instant or after application of one load.

To be sure, the most prolific source of that most discouraging type of failures, fatigue, is in unsound metal and bad corners or lack of fillets. Fatigue, the misnomer for what has been better termed "progressive failure," occurs even in sound metal with generous fillets, but such failures are rarely met with in service tests. They do occur in service if the machine is not properly designed, but usually the time required is so long that generally a test would have been completed.

Progressive failures have been often discussed in what might be termed pathological investigations of metal in service. These discussions emphasize the number of such failures due to our "toolmaker's" desire to machine parts so nicely, with sharp corners or the barest fillets. I often think that our literature will continue to tell about them until a new generation of toolmakers arises, to whom a generous fillet is actually sacred.

Service tests have sometimes demonstrated that conclusions based upon some theory



One Variety of Service Tests Takes an Assembly and Works it Rapidly Under Severe Loads. This battery of machines checks on the quality and uniformity of the heat treated springs

evolved by laboratory work may in reality be wrong. A good example is the old Model T crankshafts, which were for some time made of 1% chromium, 0.70% manganese steel (about 300 Brinell). At times they broke by fatigue in service. On being replaced with a plain carbon steel shaft of the same manganese, failures ceased. The fatigue strength or endurance limit of the alloy steel, at the same hardness as used and as determined in the customary rotating beam machine, would be much higher than that of the simpler steel of the hardness to be found in the center of the new shaft. The new one was hardened on the outside to a figure that in laboratory fatigue tests is very erratic, but the whole combination of hard shaft shaded to a soft center was completely successful in service tests. In these service tests the center main bearing was deliberately machined out of line so that the test duration could be shortened to a reasonable time. This shows how results predicted by fatigue tests on laboratory specimens may be exactly the opposite to the real performance in service.

When front wheel brakes were introduced, service tests had to be made in order to determine how to redesign the front axles. The new brakes imposed heretofore unencountered torsional stresses on the usual I-beam section. The way to know if the intended strengthening was accomplished was to run the car and observe the braking action. Here rigidity was the vital factor, a quality only to be had by proper distribution of metal and to which heat treatment adds nothing. (This statement brings to mind the thought that metallurgists cannot yet alter the modulus of elasticity, and S.A.E. 3240 is no more rigid than S.A.E. 1010.)

To return to our old bugaboo, fatigue, it is given as an explanation of gear tooth pitting. Wickenden, in METAL PROGRESS for March, called attention to this so-called wear and stated that it could be cured by harder (that is, higher strength) gear surfaces. Service tests made by running cars in second under severe loads, with gears hardened by prolonged soaking in an actively carburizing cyanide bath, have demonstrated this truth.

Davis, in *Transactions*, A.S.S.T., 1928, called attention to a number of metallurgical factors that may contribute to quiet gears. Some of these factors are not so often realized, though their effects are readily noted in our service tests of cars. Among them are distortion due to grain flow and hardness.

Wear of the type found on pump shafts at the packing bushing is one that has been studied by these service tests. Here we have found that the hardest bearing metal is not necessarily the best for day-in and day-out operation.

Changes Due to Changed Gasoline

A few years ago the introduction of ethyl gasoline imposed a different and more or less acute problem on the metallurgist. If motors were not in the pink of condition, the doped gasoline corroded the valves quite quickly. The fault was corrected after we acquired a different conception of the best valve metal and only cured by the application of results secured by testing motors in service.

Such a test as just cited may in reality be made on a motor alone, rather than a motor in a car, and by my definition of "service test" be

such. In the same way tests may be run on other units and yet be service tests. As an example, the introduction of the roller type of free wheeling necessitated tests of the transmissions run alone so as to study the steel for the cam surfaces. These tests developed failures quite different in character from the ones expected merely in consideration of available data.

Brakes, particularly brake drums, are metal parts that have been particularly interesting. It is scarcely necessary to point out the conditions that have brought them into recent prominence — faster speed and quicker stops. Brake drums of yesterday were drawn of sheet steel, an operation which, to be done cold, requires a low carbon steel. The next development was to higher carbon steels, sometimes heat treated. This frequently necessitated hot forming. Interest now centers on the use of cast metal — simple gray iron, alloyed iron, and malleableized iron — cast in stationary or spinning molds.

In all of this development there has been some laboratory test work on the materials to predict the wear resistance, but the real laboratory has been some stretch of road. Grades that are long enough and steep enough to make the older drums score (or expand enough to "fade out" the brakes) have shown what changes have been in the right direction. This work, as in other later development of laboratory machines, has given us methods that may enable us to sort out the more promising drums, and thus reduce the total amount of service testing.

Service testing of structures difficult to analyze, such as a wheel, may be done by cutting away part of them and then running them in service. To determine the safety of wheels the spokes may be trimmed down or cut away and the car run over ordinary roads.

To sum up, we may say that from a metallurgical point of view there are two ways which wear occurs. The first one is the more common one: "How will the parts resist the abrasive action met in operation?" The other: "Will the structure wear as a whole; will it have sufficient strength in all of its component parts and as a unit, to withstand the stress imposed upon it by the service it is called upon to perform?" It is this latter type of wear that we usually study by a service test when a design is complicated and the stresses imposed in service are difficult to analyze. Such service tests are often shortcuts to the knowledge that the parts are adequate.

From a metallurgical viewpoint perhaps the main thing to be emphasized about service tests is that we must at all times realize that our laboratory tests come second. They have as their function the task of measuring or appraising structures already found satisfactory in experience, so that we may thereafter make others equally satisfactory.

Service Is the Real Test *Photo by Rittase*

Gray Cast Iron, Photographed at 1000 Diameters, After Polishing With New Method. Six constituents in one field: Graphite, one flake containing two small cementite crystals, ferrite, pearlite, phosphide eutectic, sulphide inclusions. Etched with nital

By S. F. Urban and
Richard Schneidewind
Dept. of Engineering Research
University of Michigan

Dry polishing will retain graphite & inclusions

POLISHING of the gray and malleable cast irons for a metallographic examination at high magnifications presents considerable difficulty. Particles of graphite, being quite friable and comparatively soft, may be pulled out of the metal. Metal at the edge of the cavities is then rounded down.

For example, the graphite in malleable iron frequently assumes a crab-like shape but, after polishing the specimen by the usual powder-and-water methods, this constituent appears roughly circular under the microscope. At high magnification it will be found that the area in immediate contact with the graphite has been worn away to such an extent that the edges are entirely out of focus. Furthermore, the color of the graphite will appear to be black, whereas its color is actually gray.

Two methods of polishing (differing only in preparatory procedure) have been developed at the University of Michigan which do not tear out the graphite and permit one to make satisfactory photomicrographs at 1000 diameters or higher.

The usual powder-and-water method of polishing consists of the following steps:

1. Very light grinding on a fine emery wheel, or similar abrasive.
2. Grinding on a canvas covered disk with 3-F alundum powder wetted with water.
3. Polishing on a broadcloth covered disk with 10-F alundum powder wetted with water.
4. Polishing on a broadcloth covered disk with 65-F alundum powder wetted with water.
5. It is then finished by polishing with water alone. If desired, another wheel with levigated alumina may be used.

This method gives the unsatisfactory results mentioned above and shown in the upper view on the next page.

The methods which proved successful contain significant features of those described by Herty, by Burgess and Vilella in *Transactions*, A.S.S.T., 1925, and by Wohrman in *Transactions*, 1928, for polishing steel prior to examination for non-metallic inclusions. The principle is to avoid loose powder abrasives and water. Jewelers' rouge (which consists of rouge cast in a stearic acid base) is used instead, and only enough water is put on the disk to act as a lubricant.

One of the methods developed at the University of Michigan proceeds as follows:

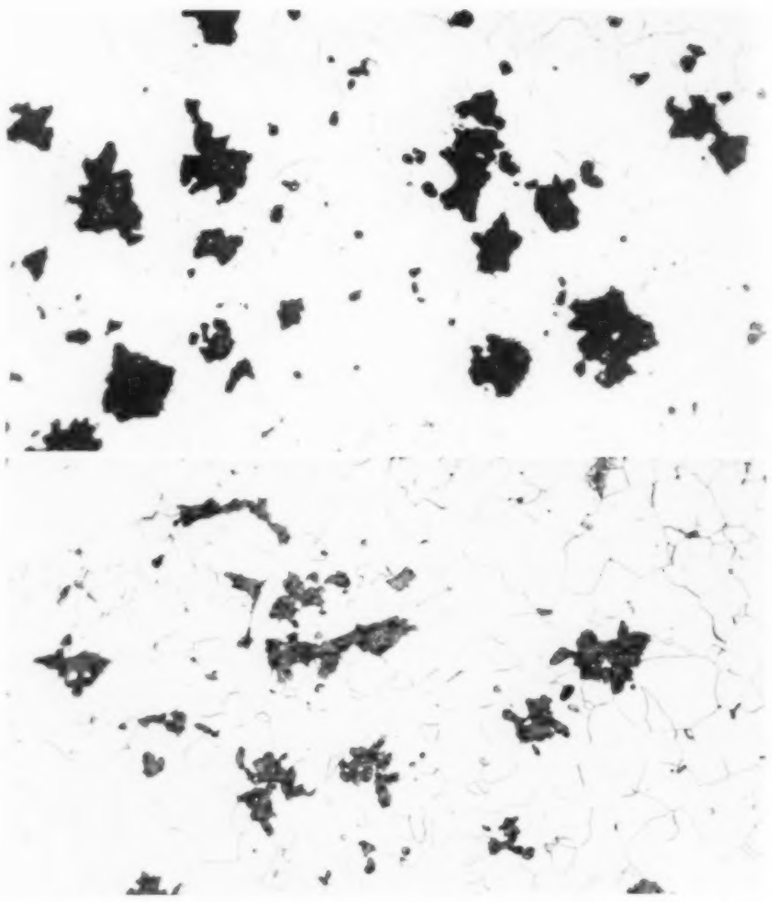
1. Very light grinding on a fine emery or abrasive wheel.
2. Grinding at right angles to the direction of the previous operation on a No. 1 French emery paper.

3. Same with 0, 00, 000, and 0000 papers successively.

4. Removal of the last scratches on a used 0000 paper which has been glazed over by rubbing it with a stick of graphite (a graphite electrode will serve satisfactorily).

5. Polishing on a disk covered with a good grade of billiard cloth, moistened and charged with fine jewelers' rouge. Water is dropped constantly on the disk and in quantities sufficient only to act as a lubricant.

The other method was evolved during an investigation on short-cycle malleable iron sponsored by the Committee on Industrial Research of the American Gas Association. It differs from the one described immediately above in the fact that steps 2, 3, and 4 are replaced with a treatment on the face of a leather wheel. This wheel is a glued sheepskin wheel such as used by electroplaters, 8 in. diameter with a 1-in. face, running at 1750 r.p.m. In detail the new method is as follows:



The Same Piece of Malleable Iron, Polished in Two Ways. Magnified 150 dia. Old wet method (above) removes the graphite and the hole is enlarged. New dry method (below) preserves the complete structure

1. Very light grinding on a fine wheel.

2. Polishing on a leather wheel charged with "stainless steel bufling compound," a mixture of alumina and pumice cast in a stearic acid base.

3. Polishing on a leather wheel or on a disk covered with billiard cloth, either one charged with "chromium plate bufling compound," which is alumina cast in a stearic acid base. If the disk is used, water is dropped on sparingly.

4. Polishing on a disk covered with billiard cloth and charged with jewelers' rouge, cast in stearic acid as above.

The leather wheel has proved to be very rapid. With some practice the operator can produce specimens with edges less rounded than specimens polished with the usual powder and water method. In fact, we have made photomicrographs out to the very edge of a piece of malleable iron at 500 diameters without touching the fine focusing screw. This without mounting the specimen in fusible metal.

Accompanying figures show the structure of malleable iron at 150 diameters, after the sample was polished in this manner. The large view on page 38 shows gray cast iron at 1000 diameters. The graphite has a distinct structure. It is not jet black, but gray, as may be easily demonstrated by polishing a block of Acheson graphite and looking at it under the ordinary metallurgical microscope.

In conclusion, it may be remarked that this method of polishing is quite suitable for studying inclusions; they are cut through, rather than dragged out, and their nature may be inferred by their color and structure, rather than from the shape of the hole which they have left behind them.

Staff Article

Industrial research as a profitable business

"RESEARCH pays dividends," is a statement to which many executives would subscribe, but most of them would assent not because an actual balance sheet had been struck, but because of the obvious success of research organizations maintained by outstanding industries such as General Electric, Eastman Kodak, du Pont, and Aluminum Co. of America. General Motors Research Laboratories need not justify their existence by such analogies. Their income from some of their developments more than covers the cost of their expanding operations, thus leaving a comfortable balance as a contribution to the surplus of the parent corporation.

This fact has had an undoubted influence on the steady development of the Laboratories. Started on a relatively small scale in the year 1920 at Dayton, Ohio, the organization later removed to larger quarters specially provided in the newly constructed General Motors Building in Detroit. By 1928 it threatened to burst these bounds, so an 11-story building all its own was erected across the way. The new structure houses chemical and physical laboratories, shops, drafting rooms, library, executive offices, and all facilities necessary to an organization maintained to seek new information.

Research paying its own way, and able to demonstrate it on the current balance sheets, is worthy of a second look. It must be remembered that each of the manufacturing subsidiaries of General Motors Corp. has control and development laboratories suited to its own needs. Cadillac, for example, has a building and staff nearly as large as the central research organization, and it is to be given entire credit for the design and development of the various Cadillac and LaSalle models. How, then, does the central research organization fit into the corporate activities?

General Motors Corp. has established an Engineering Division of the General Staff under the direction of a vice-president. Heading up to him are six important groups: (*a*) Research Laboratories, (*b*) Proving Ground, (*c*) Patent Section, (*d*) New Devices Section, (*e*) Foreign Engineering Liaison Section, and (*f*) Photographic Section.

A Technical Committee, whose members are the head of this Engineering Division, the chief engineers of the major manufacturing divisions, the head of the Research Laboratories and a representative of the Patent Section, holds frequent meetings to discuss technical problems common to all.

From this committee originate many of the

"projects" put under way at the Research Laboratories. Even though the project would originate with Chevrolet, for example, the problem (if judged to be of general interest to the other subsidiaries) would be studied in the central laboratories, progress reports and final reports sent to appropriate men in all divisions, and the cost of the work met from appropriations from the Corporation's general fund. Other projects are off-shoots or continuations of such specific studies, and may be described as fundamental or forward-looking investigations proposed by engineers or research men on the Laboratories' staff, and authorized after consideration by the executive head.

Research Work is Fundamental

Little of the work concerns development for immediate production, as such problems are handled at the various manufacturing plants. It can be described as more fundamental than practical; it is closer to theory than to production. On the other hand, diversions into "pure science" are rarely authorized. The constant endeavor is to have information available about the essential automotive materials and mechanisms before it is needed. Facts must be found to help the manufacturing divisions make each new model better than the one before.

It follows that the Research Laboratories are usually working several years ahead. Much of the work is on matters which are somewhat distantly related to the present status of the industry. The aim, as stated in an official pamphlet, is to "foresee changes and have improvements ready to help keep everyone moderately dissatisfied with what he has, and enthusiastic for the new and truly superior thing. Research is the insurance General Motors pays to help the manufacturing divisions keep just ahead of the calendar; research is planning to do something before it has to be done."

In the pursuit of these investigations (about 175 projects were active during the early months of 1932) a group of men have been trained who are being constantly called upon to help solve problems arising in all the subsidiary companies of General Motors.

Another important influence is exerted on the production of motor cars: In years when the industry is active, numbers of the staff members are drafted into the manufacturing units this turnover amounting to 10% in certain years. While this involves the serious problem of recruiting and training a constant stream of men for investigative work, the director of the Research Laboratories believes that his organization is properly functioning when it supplies men no less than ideas to the associated organizations.

Activities in the General Motors Research Laboratories are divided into sections and these classified into three groups, (*a*) mechanical engineering, (*b*) science, and (*c*) auxiliary services such as shops, accounting, and library. Immediate supervision of the section heads is exercised by the technical director and the business director. Both report to C. F. Kettering, vice-president of the Corporation and general director of the Laboratories. Among the sections conducting research may be mentioned chemical research, metallurgical research, fuel research, lighting, power plant, dynamics. The organization is rather flexible and has been built about the available personnel rather than on a strictly logical basis. For instance, the chemical section tests metal in tension, torsion, or fatigue; X-ray work, even crystal diffraction analysis, is done in the electrical section. Such a plan of operation occasions no complications in an organization of about 150 investigators, shop men, and clerical employees, for no fences have been erected, separating one section from another.

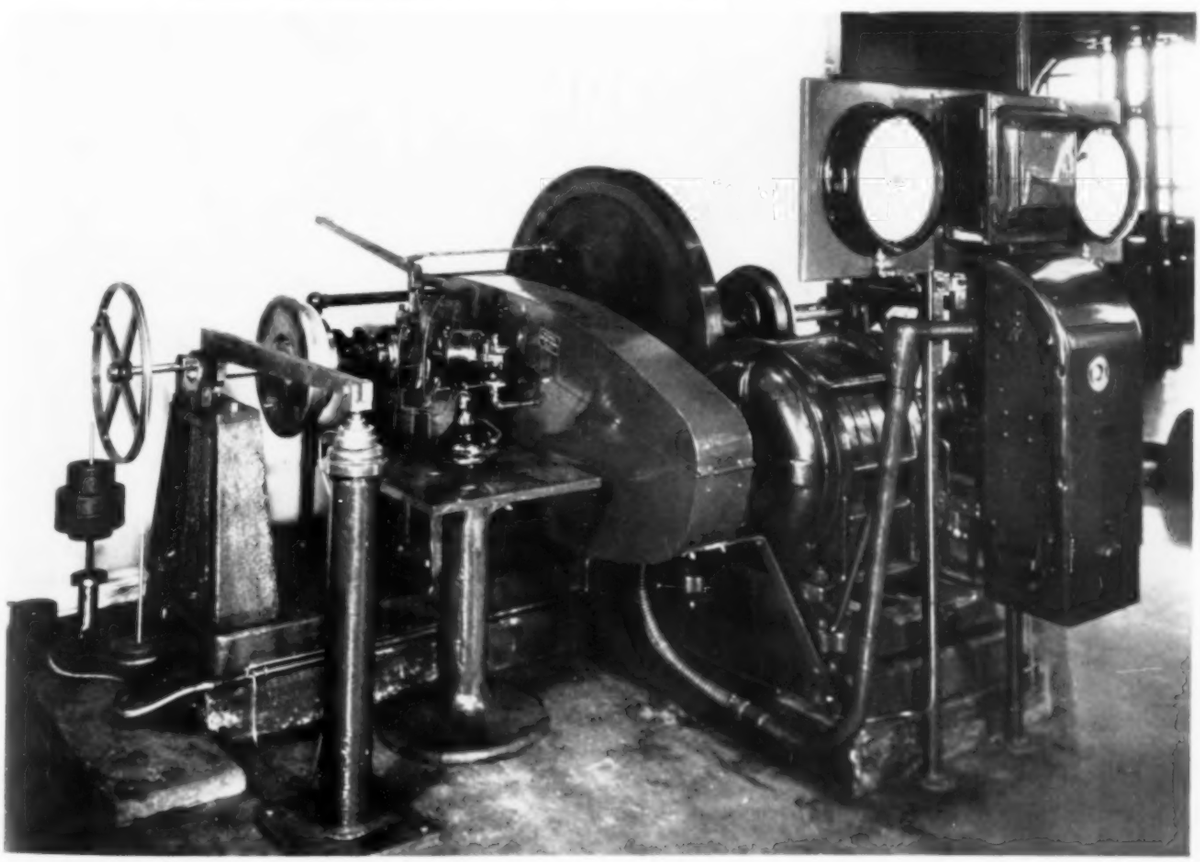
In general, the activities of the various sections may be briefly characterized. The chemical section studies metallic and non-metallic materials which go into the construction, finishing, furnishing, and lubrication of the car. It aims not only to improve them but to make better use of them in the state now available. Much specialized work on metals is carried by the metallurgical section which searches for facts about the treatment, fabrication, and utility of commercial metals and alloys and newly proposed ones. The fuel section studies the combustion of hydrocarbon vapors. Lighting section works out problems concerning headlights and lenses in a 28x115-ft. dark room. Power plant and dynamics sections study gas engines as a piece of machinery in operation, and as a problem in mechanics and thermodynamics. As

might be supposed, the latter are the busiest sections, as gaged by the number of open projects at a given time.

Prompt dissemination of information concerning the activities of the Laboratories has become an increasingly difficult problem, not only because of the large number of projects under study and the diversified operations of General Motors Corp., but also because of the well-known aversion of research men toward literary labor. The problem has been solved by organizing a Technical Data Section which attends to the work of obtaining and editing reports, and distributing them to proper men in the manufacturing divisions. The more difficult task of extracting the data from the researchers is solved by appropriating money for the projects at quarterly intervals. Three months after starting work a report is required; a "control committee" of section heads and executives then appraises the results, decides whether it should be continued, and authorizes necessary funds for the next three months. The system is "no report, no appropriation." It works very well.

It must be remembered that all the subsidiaries of General Motors are autonomous units; consequently, none of them is under compulsion to adopt the findings of the Research Laboratories — even though the problem solved were one proposed by a manufacturing division — any more than it is obligated to follow the advice of its consultants. In other words, the Laboratories must sell their ideas to the subsidiaries. Noteworthy laboratory developments which have been put into production by various manufacturing divisions are articulated and vacuum booster brakes; crankcase ventilators; lash adjuster for zero valve clearance; fixed focus headlights; double range, three-filament headlight bulbs; and carburetor intake silencers. Well-known and profitable discoveries marketed by other corporations include tetra-ethyl lead anti-knock compound (marketed by the Ethyl Gasoline Corp., owned jointly by General Motors and Standard Oil Co. of New Jersey) and Duco lacquer body finishes (developed in

Machine for Determining the Characteristics of Brake Shoes, Drums, and Linings



A Group of Flywheel Molds in the Experimental Foundry Where Extensive Investigations of Cast Iron Were Made

conjunction with the du Pont Co. and manufactured and sold by the latter).

Many of the projects now under way and completed in the past require a study of certain properties of available metals. In this the metallurgical section lends aid as cooperator or prosecutes the main investigation. At the present time much specialized test equipment is being operated to determine the wear of brake drums, bearings and gears. Some of this is a part of a study on the rear axle centering in the dynamics section and continued for the past five years. Fatigue studies, correlated with information from service via the field, have enabled the production engineers to get the best shapes on gear teeth, to fix upon a preferred steel and heat treatment, and to refine the design of details. The net result is not only that axles are stronger (therefore safer) but also lighter (the unsprung weight is reduced and riding qualities of the car improved). An important collateral result affected lubricants, since it was found that small additions of compounds, such as of sulphur, to ordinary heavy oils would prevent metal-to-metal contact even at pressures as high as 25,000 lb. per sq.in. — a result which the accepted fluid film theory of lubrication would pronounce impossible.

Other metallurgical projects include the study of structural or engine parts where a better material is desired. The conventional steels and alloys are closely scrutinized to find out whether their properties cannot be improved by changing the heat treatment or by changes in the composition or purchase specifications. Other alloys on the market, both new and old, are also studied to discover their availability for the service in question.

Foundry Practice Studied

An extended study on the fundamentals of foundry practice was completed by the metallurgical section several years ago. Pig iron was secured from eleven different sources, and all possible information was secured concerning the blast furnace operations. A small foundry making flywheels was placed under scientific control. As certain practices were varied, the effects on the castings and on a variety of test

specimens were studied. The result was an accumulation of exact knowledge about many controversial practical questions, which has been applied time after time by the foundry managers of the various manufacturing divisions. It also has enabled the Research Laboratories to give a prompt opinion upon questions frequently asked about this common and much misunderstood metal.

From what has already been said, it is apparent that the Research Laboratories seldom study problems of production, such as gear cutting, forge practice, or die design. Two or three notable exceptions relate to the manufacture of specialized equipment developed during more fundamental studies. Machines for balancing flywheels, crankshafts, propeller shafts are examples; they were developed to determine quickly and accurately the amount and location of metal necessary to be removed from a rapidly rotating piece in order to eliminate static and dynamic unbalance. Once developed, such machines were built in sufficient number in the laboratories' shops to equip all the manufacturing divisions. Production equipment for gaging the shapes of reflectors and lenses and appraising the performance of the assembled headlight is another instance. A third is a section of the shop which sets diamonds in boring tools used in all the Corporation's machine shops.

Since most of the work in progress is for the future, there has been little curtailment in staff or activities during the past year. Substantial improvements are required by consumers each year. General Motors Corp. believes that the future will intensify this demand. Improvements in products that are already good cannot be made by waving a magic wand, or by rubbing Aladdin's lamp. No rumple-haired genius muses in a secluded room until he suddenly bursts forth with an "Ah, I have it," to startle the world. Improvements are the result of patient plodding along a difficult road; of clear thinking, accurate experimentation, and careful observation. This is what is expected of the Research Laboratories.

Spectroscopes Are Used for Detecting Impurities in Materials

Correspondence and foreign letters

CHICAGO — THE ARTICLE on abnormality, in the May issue of METAL PROGRESS, by Dr. F. Duftschmid and Dr. E. Houdremont would seem to call for some comment because of the inferences that one might unguardedly draw from it.

The authors have indeed made a valuable contribution in showing that pure iron is abnormal, but it seems that one would be going contrary to existing evidence to conclude that purity is the usual cause of abnormality.

In discussing causes, one should keep in mind their statement that abnormality was associated with "a rapid state of crystallization" below A_1 (or — as suggested previously by the undersigned in the 1930 Campbell Memorial Lecture, *Transactions*, A.S.S.T., 1930, p. 601 — "the carbide diffused below the critical temperature the fastest in the most abnormal steels"). If this is true (and it seems reasonable), then an element which increases speed of diffusion would contribute to abnormality. The evidence presented in the Memorial Lecture and by J. D. Gat in an article on "Normality of Steel," *Transactions*, A. S. S. T., 1927, p. 376, seems to be adequate that dissolved oxygen increases speed of diffusion, and since Houdremont and Schrader (Ueber die Wirkung des Kobalts im Kohlenstoffstahl, *Kruppsche Monatshefte*, January 1932) have now shown that cobalt does the same, it becomes more probable that there are still other elements which have the same effect.

One is led to believe also that some aspects of the existing literature may have been overlooked by the authors. Thus their statement that "fine grain . . . is invariably attributed to abnormal steel in the existing literature" is hardly in accord with the undoubted fact that, beginning with J. D. Gat, most writers on the subject have clearly distinguished between abnormality in steel and fine grain.

Also, while it is true that oxygen pickup in carburizing "fails to account for . . . abnormality in the pearlite of the core" (*when it exists*), nevertheless when (*a*) a steel is carburized with oxygen pick-up and becomes abnormal, and (*b*) the same steel is carburized without oxygen pick-up and remains normal, it seems difficult to escape the conclusion that oxygen at times plays an important role. This was pointed out in the Campbell Lecture.

Purity Is Not the Usual Cause of Abnormality

Meanwhile one awaits further data with much interest.

MARCUS A. GROSSMANN

SCHWEINFURT, *Germany* — YOUR April issue contained Albert Portevin's letter on the determination of oxygen in steel. After summarizing the various methods proposed, he observed that the most dependable methods are the determination of total oxygen by reduction with carbon in a vacuum and the determination of alumina and silicate after volatilizing the hot sample in chlorine.

I desire now to report some recent European work on the hot extraction or carbon reduction method. Foundation for the development of present-day apparatus and procedure was laid in Aachen by Prof. Oberhoffer in 1918, whose untimely death occurred in 1927.

Up to five years ago the temperature used in Germany was limited to 1200° C., which necessitated the use of pig iron to lower the melting point of the sample. The types of furnaces and crucibles then in use did not permit higher temperatures without introducing large errors in the results. Crucibles made of refractory oxides which will not be reduced at the required reduction temperatures are, we now know, unobtainable.

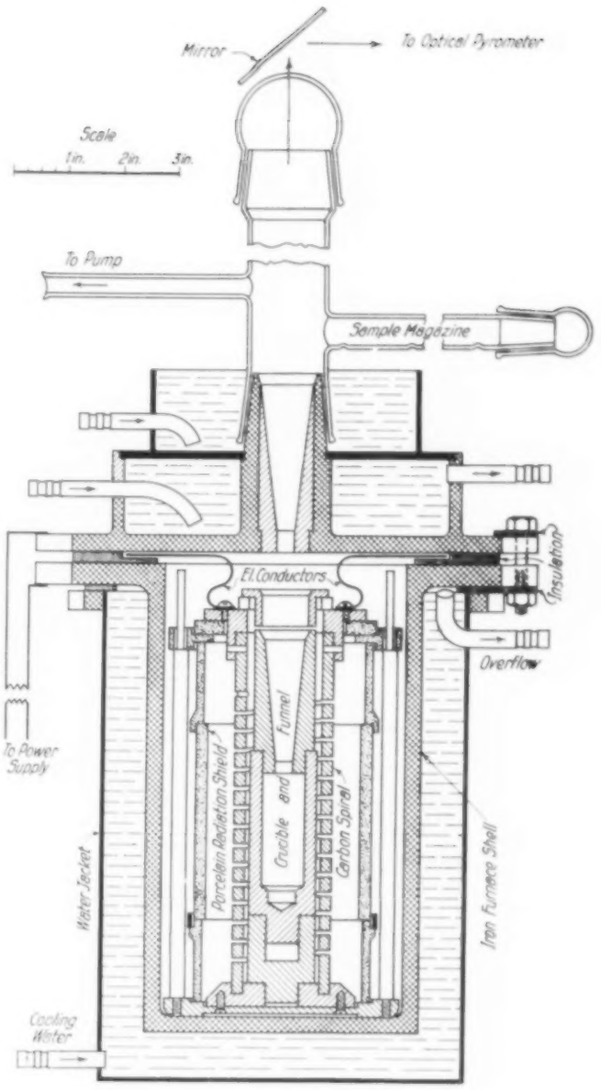
That all oxides in steel were reduced at 1200° C. soon became doubtful; this has now been proved true of the difficultly reducible silicate and alumina. Furthermore, many metallurgists showed that calculation of the oxygen content could not be based upon an analysis of the CO and CO_2 evolved, because other gases such as SO_2 were formed.

Use of high frequency furnace and graphite crucibles introduced a new epoch in the art of hot extraction, which was begun about six years ago by Jordan and Eckman at your Bureau of Standards, and was promptly taken up in Aachen and brought to a higher degree of perfection principally by means of a diffusion pump with more rapid suction. Notes on these researches and others based on the same methods are collected in the table. Throughout all of these investigations the following aims are apparent:

Determinations of Total Oxygen & Nitrogen in Steel

1. Simple, dependable apparatus. 2. Increased temperature. 3. Quantitative reduction of all oxides, including alumina. 4. Knowledge that besides CO, CO_2, H_2, N_2 practically no gases are formed or are produced by secondary combination. 5. Prevention of errors due to absorption of gas by films of condensed metallic vapor (manganese and silicon). 6. Short experimental time and increased accuracy. 7. Simultaneous hydrogen and oxygen determinations and especially a dependable analysis for nitrogen.

The above-mentioned aims were realized in the work of Hessenbruch and the present writer. Dissemination and amplification of this knowledge in three different countries leads to the firm conviction that, under differing experimental conditions, quantitative determinations of total oxygen can be successfully made, except



Cross-Section of Diergarten's Vacuum Furnace, Heated With Graphite Spiral

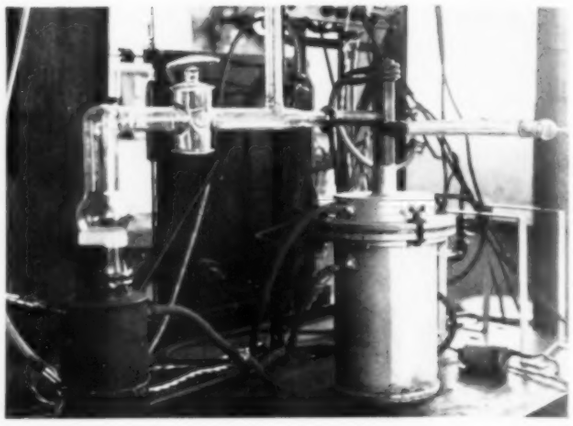
for a few steels with exceptionally high manganese and aluminum content.

Results of check analyses of oxygen on 10 to 12-gram samples usually vary no more than 0.0002%, though this depends somewhat on the type of steel. Analyses of 16 easily reducible open-hearth or electric steels of usual oxygen content can be made in 10 hr., if a proper magazine for samples is used so the furnace needs to be degasified but once.

While the high frequency furnace has been favored by many analysts, a substitute can be built cheaply and operated on a 110 or 220-volt lighting circuit. This is heated by a graphitized carbon spiral; the drawing shows one of several forms described by the undersigned in *Archiv f. Eisenhüttenwesen* in 1930. An improved modification has been devised by René J. Castro and will shortly be described in that publication.

I have become familiar with Castro's very excellent results from visits to Aachen, and he writes me as follows about his latest work:

"Correct temperature for complete degasification of the furnace within 2 to 2½ hr. is 2000 to 2200° C., with a final vacuum of 0.001 mm. of mercury. In order to carry through an analysis, the temperature can be lowered to 1600 to 1700° C., depending upon the steel and the method of deoxidation. Pressure at this temperature is 0.0001 mm. of mercury and less. The quantitative reduction by extraction methods in a vacuum — that is, the continual removal of the gases of reaction — may be said to be a thermodynamic process, and 0.0001 mm. pressure may be regarded as a vacuum.



Improved Diergarten Vacuum Furnace (at Right) Attached to a Meyer-Castro Diffusion Pump

"Accordingly, the value of the blank is reduced to 0.02 to 0.03 c.c. of CO in 15 min. Usually the Eisenhuttenmännisch Institute, Aachen, works with a blank of 0.10 c.c. in 30 min., which corresponds to the accuracy of the gas analysis.

"I send a photograph of the furnace in its present state. The connection between the furnace and the diffusion pump is very short and wide so as to raise the extraction speed. A new and improved mercury pump, made by Ludwig Mohren, Aachen, collects the gas. It has two or three times the suction capacity of former models, and costs about half.

I *Jordan and Eckman* *1925* *Bureau of Standards*	*II* *Hessenbruch and Oberhoffer* *1927 to 1928* *Aachen*	*III* *R.V. Seth* *1928* *Stockholm*	*IV* *Thanheiser and Müller* *1929* *Düsseldorf*	*V_a* *H. Diergarten* *1929 to 1930* *Aachen*	*V_b* *H. Diergarten* *1929 to 1930* *Aachen*
High frequency *Quartz* *Graphite*	*High frequency* *Quartz* *Graphite*	*High frequency* *Water-cooled quartz* *Graphite*	*High frequency* *Quartz* *Graphite*	*Carbon spiral* *Special form of II*	*High frequency* *Quartz* *Special form of II*
1600 *1400 to 1500*	*1600* *1300 to 1500*	*1650* *1300 to 1500*	*1550* *1500*	*1850* *1600*	*1650* *1400*
50% of total gas	*10 to 30% of total gas* *0.0020*	*Very small*	*Up to 20% of total gas* *0.015*	*Under 10% of total gas* *0.2 c.c. gas in 15 min.* *0.0008 to 0.0015*	*Same as V_a*
Unknown	*From a magazine in vacuum* *10 g*	*In vacuum by a column of Hg.* *25 to 50 g., max. 100*	*Same as II*	*In vacuum, through a side tube by a magnet.* *Of such weight that correction will be less than 10% of total gas*	*Same as V_a*
4 to 8 hr.	*20 to 40 min. for normal steel*	*20 to 30 min. for normal steel*	*Same as II and III*	*Somewhat longer than V_b*	*20 to 60 min. for normal steel*
H_2O, CO_2, CO as CO_2 gravimetric by absorbtion tubes	*H_2, CO_2, CO, N_2 volumetric*	*Same as II*	*Same as II*	*Same as II*	*Same as V_a*
100% assumed	*Admittedly imperfect at 1500°* *100% assumed at 1600°*	*Same as I*	*Quantitative reduction of SiO_2 and Al_2O_3 doubted*	*Proven that all known oxides, including Al_2O_3 reduced quantitatively above 1550°*	*Same as V_a*
Use of turnings for samples and oxide refractories for crucibles finally abandoned.	*Introduced diffusion pump with more rapid suction. Interference of Mn vapor films noted.*	*First to work without diffusion pump. Difficulties encountered with Mn vapor films.*	*Apparatus cleaned after every analysis to prevent effect of manganese vapor.*	*Al vapor films do not affect irreducibility of Al_2O_3, N values not influenced by Mn and Al vapor films.*	*(Over 70 analyses performed on [illegible])*

"Fused joints are avoided so that any laboratory worker can put the pump together and use it."

It is our experience that the nitrogen determination in the carbon spiral furnace is absolutely reliable. It has therefore been possible to analyze electric and open-hearth steels by this method, and electric is known to have higher nitrogen content.

By checking the experimental data published by different investigators, such as reduction temperature, concentration of components in the melt, adjustment of the weight of the sample to the oxygen content, and maximum rate of extraction of the reaction gases, the total oxygen in steel can now be quantitatively determined.

HANS DIERGARTEN

Corrosion Studied by Laboratories in U.S.S.R.

MOSCOW, U.S.S.R. — DURING the last few years much attention has been given in this country to the question of corrosion of metals, an interest undoubtedly due to the rapid development of industry and to the organization of many scientific and research institutes. A central corrosion committee has been organized by the State Planning Department (GOSPLAN) which directs and coordinates all the practical work in this direction.

Many of our research institutes have laboratories well equipped for studying the corrosion of metals and its prevention, such as the Central Aero-Hydrodynamical Institute (C.A.H.I.), the Institute of Non-Ferrous Metals, the Institute of Metals in Leningrad, and the Institute of Materials of the Commissariat for Railways. Similar work is also being carried on by technical high schools and at factory and plant laboratories.

Special courses of instruction have also been opened at such technical schools as the Moscow Institute of Non-Ferrous Metals and the Moscow High School for Mechanical Engineers.

The first all-union conference on corrosion took place in Moscow in 1929. More than 100 representatives of industrial and scientific research organizations attended and listened to 30 reports on different phases of the question. At this conference it was resolved to limit future meetings to the consideration of more limited fields — also to call local conferences. Up to 1931 two such local meetings were held in Moscow and one in Leningrad.

The second general conference met last year to discuss the theory of corrosion and the corrosion of aluminum alloys. A number of eminent German scientists participated. Professor Mueller delivered a splendid lecture on the theory of passivity. The present writer offered a new theory based on the modern physics of

	VI Eilender and Diergarten 1930 to 1931 Aachen	VII Vacher and Jorden 1931 Bureau of Standards	VIII Bardenheuer and Schneider 1931 Düsseldorf	IX Ericson and Benedicks 1931 Stockholm	X Castro and Meyer 1932 Aachen
Furnace Tube Crucible	Same as V_a and V_b	High frequency Quartz Graphite	Same as VII	Same as III	Carbon spiral
Time for Evacuation Time for Analysis	Same as V_a and V_b	Unknown 1550 to 1600 (for Al steel)	1600 1550	Up to 1700 Up to 1700	Up to 2200 (2 to 2½ hr.) Up to 1720
Same as [illegible] Volume	Same as V_a and V_b	Similer to V	Similer to V	0.05 c.c. for 10 min.	0.02 c.c. for 15 min.
Same as [illegible] Pressure (mm. Hg)					0.0002
Same as [illegible] Method of Introduction Weight	Same as V_a and V_b	Same as II and IV	Same as IV	In vacuum through side tube 10 g., for small amounts of gas	Same as V and IX
[illegible] min. 60 min. Total Time	Same as V_a and V_b	Same as II	Same as II and III	40 to 50 min.	30 to 40 min.
Same as [illegible] Gas Analysis	Same as II	H_2, CO_2, CO, N_2 gravimetric and volumetric	Same as II	Same as II	Same as II
Same as [illegible] Oxides Reduced	Same as V. Quicker reduction of Al_2O_3 above 1550	Quantitative for all oxides	Same as VII	Quantitative reduction of all oxides except Al_2O_3 (92% of Al_2O_3 sufficient for practical purposes.)	Same as V and VI. Quantitative for Al_2O_3 at 1700°
Remarks	Proved that carbon spiral furnace gives quantitative values for steels having up to 0.6 Mn and 0.2% Al.	Quantitative determination of oxygen and nitrogen in steels containing up to 0.05% Al and 0.8% Mn.	Prevented condensate of Al. Determines total oxygen in most technical steels. (Mn up to 1%)	Procedure reliable not only for carbon steels and irons but also for alloy steels. (Al up to 2%; Mn up to 3%)	Quantitative determination of total oxygen with Mn up to 3%. Apparatus now reliable and quick.

metals and on the mechanism of polarization and depolarization, applying his theory to solve questions concerning the structural corrosion of alloys.

Dr. Ragnitz described the methods used in Germany for the protection of light alloys. Kroenig, of C.A.H.I., reported the latest work in this field done in Moscow which showed valuable results in the protection by zinc, the influence of contacts with other metals, and in new alloys with great corrosion resistance. A reciprocal understanding between Soviet and German scientists was attained through interesting discussions.

The next conference will be on the subject of stainless steels and is scheduled for the fall. It will also be attended by foreign investigators.

GEORG W. AKIMOW

Rules for Guiding Corrosion Research

PARIS, *France* — THERE is no other property of metals so complex as its chemical resistance (or its opposite, corrosion by chemical agents). No less than twenty factors may be enumerated which influence the phenomenon; they depend on the external medium, or on the metal and its history, or else on the piece and the way it is used. Moreover, one of these factors, the chemical nature of the external medium, possesses a certain character of infinity, as it comprises all possible products and chemical mixtures. Consequently, the general statement may be made that no alloy exists which is truly resistant to chemicals; some metals and alloys may resist some certain attack; other alloys which resist in special circumstances will be attacked in others.

It is easy to understand why research into chemical resistance cannot be readily directed by general principles. And yet it is possible, from what is already known, to state some important rules. These may be called

1. Principle of homogeneity,
2. Principle of critical concentration in solid solutions,
3. Principle of auto-protection.

Homogeneity. This principle may be stated thus: Any chemical or physical heterogeneity in the metal *tends* to increase corrosion in an electrolytically conductive medium by forming local couples.

For example, when an alloy composed of two or more constituents is dipped into an electrolyte, some electrolytic influences will quicken the solution of the less noble constituent (and consequently tend to provoke the disintegration of the whole) owing to the differences of solution potential between these constituents.

For such services, chemically resistant alloys must be sought among those having only one constituent (that is to say, a solid solution). A definite chemical compound also answers the specification but it is generally hard and brittle and frequently useless; it may be formed only by casting or molding. Solid solutions, on the other hand, are very often malleable and may be worked.

Any additions made to increase the chemical resistance of an alloy must consequently enter in a solid solution. Some additions, not going entirely into solid solution, may be made to improve physical and mechanical properties, but a decrease in chemical resistance must then be expected (or at least, no improvement in this respect).

The principle of homogeneity implies *uniformity in concentration* in solid solution, which may be effected by proper heat treatment, such as a long anneal.

It also depends upon electrolytic influences and thus implies electric conductivity of the external medium. Its importance becomes very small when the medium is not very conductive (such as for concentrated mineral salts) or nonconductive (for example, dry gases).

2. *Critical Concentration* — This rule may be worded as follows: When an element which goes into solid solution is added, chemical resistance often is at a peak at the maximum concentration, and consequently it may require a quenching treatment to obtain supersaturated solutions at room temperatures.

Hence comes the well-known necessity of using some alloys in a hardened state.

3. *Auto-protection.* This rule states that, except for noble and precious metals, chemical resistance comes from a protective layer or film of the reactive products that forms on the surface of the metal and preserves it from further action of the reagent.

Utilization of such a phenomenon is responsible for the development of alloys resistant to acids. The metal is not rendered insoluble but it is auto-protective precisely because it *is* soluble. It is protected in the same way as though it were painted.

But paint films, protection agents, and electrolytic deposits may peel or be scraped off, and such an injury is the locus of corrosion phenomena that are often hastened by electrolysis between the metal and the coating.

In the case of passive metals, on the contrary, the injury automatically repairs itself in the reagent. Of course, when the reagent is changed, everything is upset.

In order to obtain chemical resistance by this means, the reaction must produce an insoluble product forming a continuous, adhesive, impermeable layer, capable of a certain amount of deformation (consequently a thin but not brittle one). Adhesion of such a film, or of an artificial protection agent or electrolytic deposit, may be considerably influenced by the preparation of the surface and especially by its texture and cleanliness.

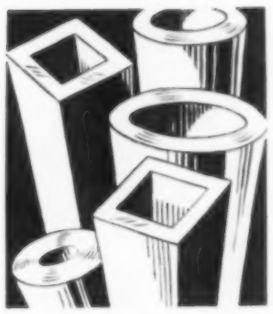
All this may be summed up in the following statement:

"One must try to produce, by adding an element which is passive or auto-protective in the medium in question, a homogeneous solid solution having a rather high concentration."

Stainless steels, with chromium as a basic element, are remarkable examples of the application of the above rules. A solid solution of alpha iron and chromium or an austenitic solution of iron, nickel, and chromium is produced which has a rather high concentration (at least 12% Cr) and is uniform in chromium — the element which acts as a passive auto-protective element when immersed in oxidizing acids. By application of the above rules we have also obtained austenitic tungsten or molybdenum steels resistant to hydrochloric or sulphuric acids.

ALBERT PORTEVIN

Nitrided Steel Used for Many Machine Parts



TURIN, *Italy* — IT ordinarily takes a long time before a completely new technical process is adopted regularly in industrial practice. This has not been true for the nitriding process which, in the nine years since its discovery by Dr. Fry, is now adopted for a great variety of technical applications, the number increasing every day.

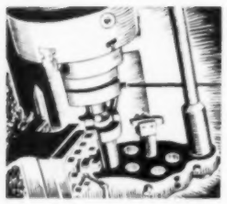
It is very interesting to note how the process has developed in different countries; in each of them it has followed characteristic lines. In France, nitriding has so far been principally applied in the automobile industry and in the construction of airplane engines. On the other hand, the new process has from the very beginning been better appreciated by other groups of manufacturers in Italy and its adoption by the automobile industry has followed somewhat tardily.

In fact, the nitriding process has been adopted since its first appearance in this country as a regular manufacturing process by makers of all kinds of small tools and machine tools. The largest factories have used it extensively for many years, with excellent results.

Advantages of nitrided steel over the best materials used previously were especially noteworthy in some typical applications. For instance, a large roller bearing factory, using quantities of cylindrical gages, found its consumption of these tools reduced by more than 85% when nitrided gages were installed.

Most excellent results were also obtained by the use of nitrided steel for parts of grinding machines, where the wheel dust acts as a severe abrasive. It has been found that some parts now last twenty times as long as before.

At present the applications are also developing very rapidly, in Italy, in practically every branch of mechanical construction including the automobile industry (where some factories have adopted it as a standard material for many parts



of motors and chassis), the manufacture of airplane engines, steam locomotives, electric locomotives, diesel engines, and pumps.

In addition to these standard applications, which are practically the same everywhere, it would be easy to quote a great number of special occasions where the use of nitrided steel has solved certain difficult and hitherto baffling problems. One of these cases occurred in the well-known Caprotti valve motion for locomotives, now used by railways of many countries. Nitrided steel in the valve rods, seats, and cams has enormously reduced the steam losses and increased the life and efficiency of the apparatus, removing completely the difficulties experienced with all other materials.

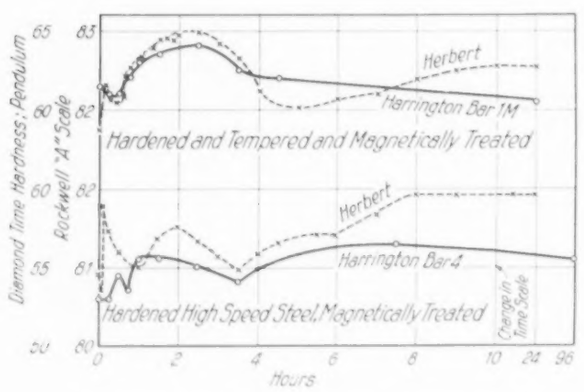
Many similar examples could be mentioned, showing that the peculiar properties of nitrided steel not only improve known machines and apparatus but also solve new problems in the field of mechanical construction.

FEDERICO GIOLITTI

Experimental Errors? or Fluctuations in Hardness?

MANCHESTER, *England* — THE JUNE number of METAL PROGRESS contains Mr. Harrington's hardness figures. These, as I anticipated, are illuminating. There is no doubt that he succeeded in setting up hardness fluctuations in each of his bars. One cannot draw a smooth curve through experimental errors.

I enclose a graph of two of Mr. Harrington's results plotted against two of my own recent results on the same classes of steel, from which you will see that the periodicity of the fluctuations is almost identical.



Hardness Fluctuations in High Speed Steel According to Harrington and to Herbert

I attribute the extremely feeble fluctuations to the use of an insensitive hardness tester, treatment at the wrong temperature (I have shown that high speed steel is best treated at 320 to 400° F.), and probably to unsuitable magnetic conditions.

I suggest that Mr. Harrington should follow up his success by discarding high speed steel in favor of high carbon steel, which is best treated cold and responds to a wide range of field strengths. Alternatively he might try a soft metal. Some of my best results have been obtained with nearly pure nickel, treated cold at induction of about 16,000 gauss.

If he wants any results worth having he will have to make tests at half-hourly intervals and keep at it for 12 hr.

EDWARD G. HERBERT

Powdered Metal Is of First Importance

PITTSBURGH — CHARLES HARDY is to be congratulated for his very interesting article on the manufacture and use of powdered metals in the July issue. "Powder metallurgy," if that phrase may be coined, is still in its infancy and has found its first recognition in the non-ferrous field. Although "powder metallurgy" in the iron and steel field is relatively in its embryo, and many hurdles will have to be crossed before it can be commercially presented, nevertheless considerable progress is being made and the results indicate large promise.

It seems needless to say that most of our metallurgical difficulties will be eliminated if steel and alloys can be made economically without passing through the molten state. One has but to recall briefly the many problems that have presented themselves that can be directly or indirectly attributed to conditions surrounding the solidification of metals and alloys from the molten state: Segregation, oxidation, for-

sign inclusions, pipes, seams, ingotism, ghost lines, non-uniformity in the results of heat treating, variables in cold forming. Unquestionably new problems will arise but it would seem that they will be more under our control than the physical phenomena of solidification from the molten state.

Wrought iron which is formed from a spongy state may be considered to be the missing link between the production of steel and alloys by melting and "powder metallurgical" processes. Synthetic wrought iron with uniform slag distribution, irons and steels with controlled impurities, and stainless alloys have been made from powders on an experimental scale by heating the loose powders (or their cold pressed mixtures) to their welding temperature, or soft spongy state and then compressing them in a suitable die while at this desired temperature. The combination of a reacting heat and pressure and cooling under continued pressure or work eliminates voids and produces metals of high density and uniformity.

Production of ferrous metals and alloys from powders will receive marked impetus when cheap powdered iron and its associated alloying metals are assured in commercial quantities. Every encouragement should be given to those working on the production of suitable metal powders, for they are creating a new branch of the metallurgical industry.

J. W. WEITZENKORN

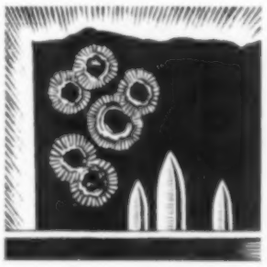
New Armor Piercing Projectile

LIVERPOOL, *England* — I RECENTLY referred in these columns to Britain's need of a little more gold. This may have been a little premature, as the papers have announced that our budget balances, and there has been a general "cough-up" of gold in its various forms. For instance, the populace seemed able to produce large numbers of golden sovereigns and half sovereigns, for which, for some days at least, as much as 27s.6d. paper currency per sovereign was paid by jewelers, a premium of 37½%.

Old family jewelry also was converted into currency. I fancy a lot of it was far too good for the melting pot. In fact, it is not impossible that some items may appear in the American market as valuable curios! Either because stores are now depleted, or because prices have fallen, this market has gone very quiet again.

Recently, also, Sir Robert Hadfield described Britain's latest deadly weapon. In conjunction with Major Clerke, he has developed what is likely to be a most important type of armor-piercing projectile, and once again England stands at the top of the tree in this respect.

This new type of shell can perforate hard-faced armor of the best quality and over one foot in thickness. More wonderful still is that this perforation can be achieved if the armor plate is inclined 30° and with a projectile velocity equivalent to a range of not less than 15,000 yd., which is about 10 miles. The time occupied in piercing the plate is about one two-hundredth part of a second.



During recent years, the tendency has been to concentrate on the development of high speed in ships, with the result that a very considerable amount of the displacement was accounted for by the weight of the engines, boilers, and power auxiliaries. Fitting of armor plate for defence has, therefore, been cut to a minimum, and ships must rely for their safety principally on extreme ranges and a high rate of fire. In fact, in most of our modern ships, with the exception of the last two, the Rodney and the Nelson, protection is practically non-existent.

Sir Robert Hadfield's discovery seems very likely to affect considerably the future design of our armored ships, whether battleships or cruisers, because the steel of which the shells are made can be used equally well for medium as well as heavy calibers.

If, therefore, we revert to heavy production of armor as well as to subdivision, we may expect to see a considerable reduction in the weight of machinery, and therefore in speed, in future war vessels. An alternative, of course, is the more generous use of heat treated steels and of light alloys.

F. G. MARTIN

Concentrates from recent technical literature

ALTHOUGH 6,000,000 to 7,000,000 lb. of metal is in circulation in the U. S. Government Printing Office, little new metal is purchased. Remelting and correcting of metal at the Printing Office in four 5-ton, gas-fired kettles is described by M. W. von Bernewitz in *Mining and Metallurgy* for July. **TYPE METAL** is remelted at a temperature of 600 to 700° F., a sample analyzed for tin and antimony, and the necessary correction metals (a 60% Pb, 40% Sb alloy, a 33% Sn, 67% Sb alloy, or a Sn-Pb alloy) are added. The melt is stirred or "poled" with a block of wood and cast into 24-lb. bars for use in the linotype and monotype pots. Stereotype metal (6.5 to 7% Sn, 13% Sb, 80.5% Pb) is corrected with 1 to 4% Bi. Electrotype backing metal is 3.5% Sb, 4% Sn, 92.5% Pb. Polished copper plates for halftones are occasionally tested for hardness and thickness in the laboratory, which also contains a photomicrographic room and a metal analysis laboratory in the Metal Section. A microscopic study of unsatisfactory zinc used in line work is under way.

ALEX TAUB, in Machine Shop Practice Paper 54-8 (A.S.M.E.), discusses "Correlation of Casting Design and **FOUNDRY PRACTICE**," and says that the price per pound of the casting is the true measure of cooperation. Bulk, for instance, is not weight of casting, but the size and weight of the flask and sand necessary to make it. A small projection on a casting may require a larger flask and put the work on heavier and slower machines. It is nearly always better to have a 110-lb. casting at 4¢ a pound than a 100-lb. one at 5¢. Mr. Taub said much about core practice and the difficulty in preventing a shift, a burn-out, or a fin in the very small spaces allowed by modern automobile engine designs. One inch more on the wheel base devoted to engine length would remove most of the troubles. Whether green sand or dry sand cores are most economical depends on the available oven capacity and particular foundry conditions. Many complicated castings can be successfully made with green sand core, highly compressed and fitted into place within the flask without being removed from the molding machine on which it is made. In attempting a revised design, the history of the old one should be examined so it will not encounter the "cost barnacles" which attached themselves to the old job after it got started. Also any new design requiring new foundry technique should not be rushed through to the experimental department until the first castings had been cut apart to make sure there are no defects.

STEEL used for the world's largest arch bridge across Kill van Kull is described by L. S. Moisseiff in *Journal* of the Franklin Institute for May. Practically all the dead load is carried by the massive bottom chord made of a **MEDIUM MANGANESE STEEL** in as-rolled condition. Average of 168 heats gives C 0.33%, Mn 1.63%, Si 0.18%; ultimate 101,600 lb. per

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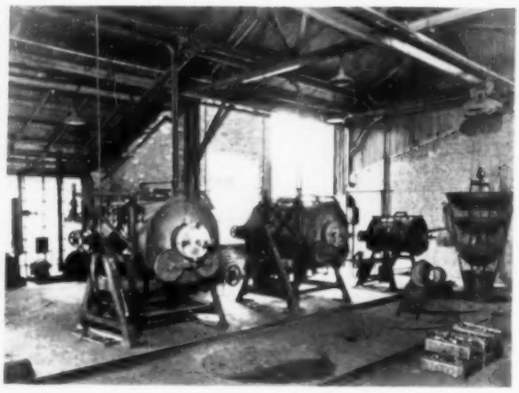

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sq.in., yield by drop of beam 58,600 lb. per sq.in., elastic limit (rate of deformation 50% greater than at origin) 46,000 lb. per sq.in., elongation in 8 in. 19.5%, in 2 in. 23.1%, reduction of area 42.6%. Since large size tension test pieces gave poor results it was decided to use this steel in compression only. Rivets of the same character, but slightly softer, were also used. Their test strength was 60% higher than conventional carbon steel rivets. In all 10,500,000 lb. of this manganese steel was used; 7,300,000 lb. of structural silicon steel was consumed principally in the upper chord, 14,900,000 lb. of plain carbon structural steel in bracing and floor system, 500,000 lb. of pre-stretched 3¼-in. wire rope in hangers, and 800,000 lb. of forged pins and bearing blocks. Average cost of steel in arch and approaches was 9½¢ per lb.

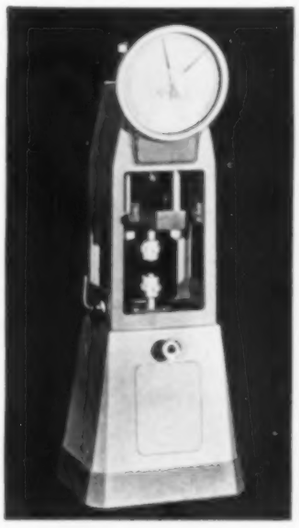
STEEL, because it is cheap and strong, is probably the commonest and most suitable material for stampings. Cold rolled steel gives best results for parts drawn to close limits; hot rolled is cheaper but only in sheets thicker than 0.035 in. Brass, while more expensive, is ductile, takes a wide range of tempers, is non-magnetic, easily plated, and has a fine grain. Other materials used for stampings are bronze, copper, aluminum, monel metal, nickel, and silver. Since cost and weight are proportional to the thickness of a part, this is an important item. J. K. Olsen, in *Product Engineering* for July, points out the confusion arising from the use of different gages and advocates the adoption of some standard. Most **STAMPING STOCK** is available in a wide range of tempers from dead soft, for parts requiring extensive forming and drawing, to spring temper, for strong, flat parts. All materials which go through a series of draws must be annealed between operations to prevent cracking. Size of a part should determine whether sheet or strip stock is to be used; coil stock is preferred where straightness of the part is not a requirement. Other factors to be considered in selection of a material are grain size and surface finish.

Concentrates

CAST IRON which is free from contamination and whose chemical composition and structure can be definitely controlled, made in a battery of rotary furnaces at the Armstrong Whitworth works in England, is described in *Metallurgia* for June. Like the Italian furnaces discussed by Dr. Giolitti in the correspondence pages of METAL PROGRESS for April, May and June, they are fired with pulverized coal, and the air supply and fuel are so controlled that any desired temperature and atmosphere can be obtained. Superheating cast iron in the ROTARY FURNACE produces a pearlitic matrix with finely disseminated nodular graphite. An automobile cylinder block of this material, metal varying in thickness from $\frac{1}{16}$ to $\frac{5}{8}$ in., showed a tensile strength of 36,000 to 40,000 lb. per sq.in. A heavy commercial casting (up to 12 in. thick) tested at 39,200 lb. per sq.in. These strengths are usually attainable only in steel.

CRACKS causing failures of medium manganese steel rails are often found to originate in what is known as a "martensitic structure" occurring at the center of the head or at the base of a rail. It consists of needle-like streaks $\frac{1}{2}$ to 2 in. long and 0.001 to 0.01 in. diameter. Spectroscopic and X-ray analyses of this structure, detailed by H. H. Morgan and J. R. Mooney in *Railway Age*, June 18, show that it belongs to the iron-carbon-manganese system and is not a true martensite. The structure is estimated to contain up to 10% manganese with a minimum of 4%. Most RAIL FAILURES due to this defect occur in rails made of the upper portion of the 0.51 to 0.67 carbon and 1.30 to 1.60 manganese range, and the amount of martensitic structure increases with increasing amounts of these elements, but hardness requirements preclude the possibility of lowering the carbon and manganese content. The defect is apparently a segregated spot in head or base, and one manufacturer plausibly claims that 0.1% Va will eliminate the structure entirely, as well as improving most of the other physical properties of the material.

The Biggest Little Universal Testing Machine in the World



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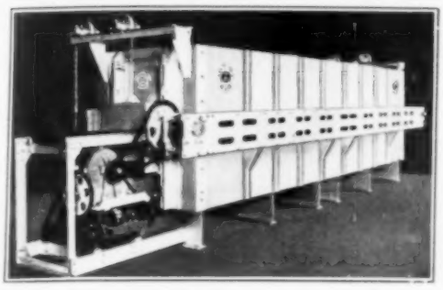
INSPECTION of structural welding entails preliminary testing and observation of the welders at work, of their manipulation of welding machines, knowledge about the surfaces and bracing of parts to be welded, and size and contour of the weld. In electric arc welding, current and voltage, sound, and sparking can be interpreted by an experienced inspector, and in gas welding the appearance of the flame must be watched. Need of continuous **INSPECTION DURING WELDING** is emphasized by F. Eder in a paper delivered to the Philadelphia Section of the American Welding Society and printed in the *Journal* of that Society for June. For a simple field test a sample weld can be made, broken, and the fracture observed. Samples can also be subjected to tensile, bend, X-ray, and magnetic tests. An acoustic method using a stethoscope to amplify the sound of a light hammer blow has also been used.

IN A summary of available information on the physical properties of **HIGH ALLOY CASTINGS** both at room and elevated temperatures, the maximum temperatures for safe use in various types of atmospheres were given by Jerome Strauss before the recent A.S.T.M. meeting. These were confined to the representative members of the iron-chromium-nickel series with or without other elements, and the tabulation made on a standard record sheet which shows clearly what data are missing. Chromium-iron alloys containing 13, 18, and 28% Cr are considered, and it is noted that these will not withstand much stress when heated and are not very tough at room temperatures. When nickel is added to rectify these matters we have a long series of alloys, eight of which are chosen as typical. To avoid carbide embrittlement of the 18% Cr, 8% Ni type, carbon below 0.06% may be specified (making an exceedingly difficult alloy to cast), or proportional amounts of other elements such as titanium or vanadium may be added, or chromium content may be largely increased. Much nickel in the alloy renders it unserviceable in hot sulphur-bearing gases. Of the



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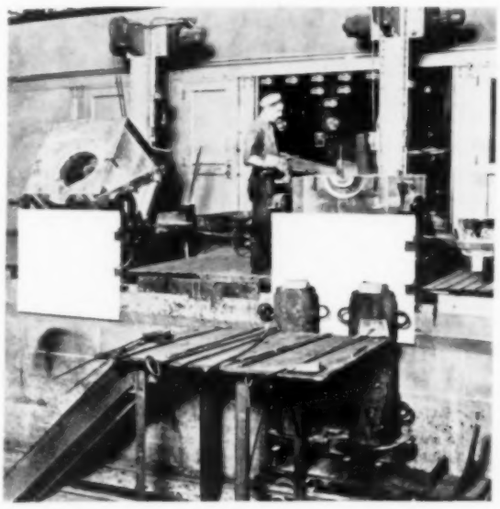
furnace castings for very hot work, three-quarters are probably made of 18% Cr, 36% Ni, 2% Si, balance Fe. Mr. Strauss emphasizes that published data on laboratory corrosion tests and strength at high temperatures are to be used with great care, in view of the lack of uniformity in test procedure and precision of the apparatus. The best way to proceed is to select one or two alloys which seem best suited and test on as large a scale as possible.

STAINLESS steel parts for pyrometers are made by Brown Instrument Co. to a tolerance of 0.001 in. in three operations — punching, blanking, and shaving. The manufacture of the very accurate dies required for this work is described by Walter C. Schmidt in *American Machinist*, June 23. Blanking **DIES FOR STAINLESS** steel are of vanadium steel heat hardened to Rockwell C-65; shaving dies are of high carbon, high chromium, and semi-high speed steel, heat treated to C-61 or 65. The former are heated slowly (about half the usual rate) to 1420° F., held for 20 min., and quenched in brine. Tempering is done at 425° F. for 2 hr. Shaving dies are heated to 1750° F., held for 15 min., quenched in oil, and tempered at 375° for 3 hr. They show no measurable distortion or shrinkage. Die clearances are wider than those used ordinarily, and cutting edges are so tapered as to provide maximum support and yet allow $\frac{1}{16}$ in. of stock for regrinding. Punch and die are aligned accurately by the use of precision die-sets which are removed only to regrind the dies.

TUNGSTEN CARBIDE cutting tools may be toughened, according to Messrs. Fink and Meyerson in the *Iron Age* for July 7, by using an alloy of cobalt and molybdenum, with or without copper, instead of the pure cobalt metal which is frequently mentioned as the best binder for the brittle carbides. During sintering the binder probably absorbs some tungsten and carbon, so its composition is quite complex.



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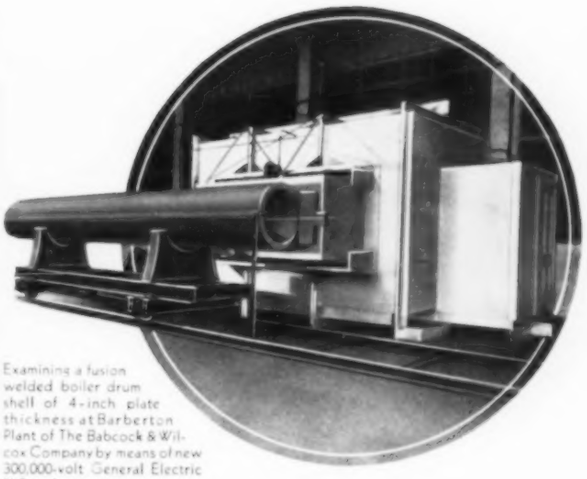


Examining a fusion welded boiler drum shell of 4-inch plate thickness at Barberton Plant of The Babcock & Wilcox Company by means of new 300,000-volt General Electric X-Ray Apparatus.

Babcock & Wilcox install 300,000-volt x-ray plant

FUSION welding of boiler drums four inches and more in thickness is routine procedure at the Barberton Works of The Babcock & Wilcox Company. To insure sound welds, equal to or better than the plate metal, they have recently installed the latest and most powerful type General Electric x-ray apparatus, for non-destructive radiographic examination of the completed weld.

Operating at a potential of 300,000 volts at 10 milliamperes, Babcock & Wilcox find that this equipment "will thoroughly explore, on a production basis, fusion welded seams up to 4¾ inches in thickness."

This is but one of the many specialized G-E industrial x-ray plants which are being installed for the examination of welds, castings, rolled and drawn materials, hidden assemblies, etc., and for crystal analysis. In practically every production process where hidden defects present a problem the x-ray can be profitably used. In many cases the x-ray negative has pointed the way to improved manufacturing methods which have eliminated the defects.

Let us keep you informed on the latest developments in this field. Literature describing and illustrating the many industrial applications of the x-ray will be sent on request. Address Industrial Department.

GENERAL ELECTRIC
X-RAY CORPORATION
2012 Jackson Boulevard **Chicago, Illinois**

Join us in the General Electric program broadcast every Sunday afternoon over a nationwide N. B. C. network.

Stability of Steel

(Continued from p. 34) speeds, either of single wires, or loops of wire around a 19½-in. shoe (with wires either pre-formed or not) break on the straight portions of the wire at expected high strengths (215,000 to 230,000 lb. per sq.in. ultimate, 35 to 40% contraction in area, and 8% elongation in 10 in.).

It should be noted that out of several hundred tension tests on the wire made at the Bureau of Standards since the first bridges were dismantled, a fairly large proportion break with a low reduction of area. Specifications under which the wire was manufactured and accepted called for the following minimum values:

Ultimate strength	220,000 lb. per sq.in.
Yield point (load to produce 0.75% elongation in 10 in.)	190,000 lb. per sq.in.
Elongation	4% in 10 in.
Reduction of area	30%

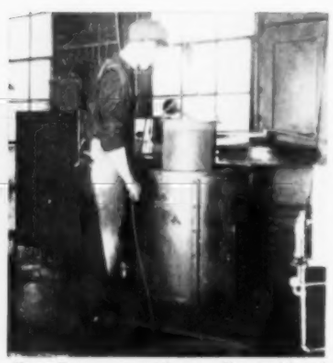
The usual range of actual values is now

Ultimate strength	215,000 to 230,000
Elongation	about 8% in 10 in.
Reduction of area	35 to 40%

While the last figure was not measured and noted on the mill test sheets, the inspector's records show that about 5% of the finished wire was rejected for obvious low reduction of area. Since the specifications allowed a retest if one break had less than 30% reduction, but was otherwise satisfactory, we can only speculate on what the chances were of finding a "low spot" in the 10 in. immediately adjacent to the first break. Consequently, data are missing to decide whether there were fewer tension tests showing low reduction in area when the wire was made than are now being found at the Bureau, and consequently some change in the wire (either internal or on the surface) is causing a gradual loss in ductility. Pending determination of this point, the most that can be said for the hypothesis that the heat treated wire is unstable in structure is that its instability, if present, has not become very evident in four years, and the course of these changes in the one year required for manufacture, erection, and dismantling would be correspondingly obscure.

As a matter of fact, the work-hardened bridge wire (the old reliable cold drawn wire) might also be suspected of impermanence, since the phenomenon of season cracking (so well known to brass fabricators) is an instance of spontaneous fracture of work-hardened metal during mild corrosion. But cold worked iron bridge wire dismantled and studied after 75 years' service gives no evidence of deterioration or internal decay. Of course parallel tests made 75 years ago do not exist, but the verdict of experience in wire mills is that cold drawn wire improves with age.

Therefore, while we must admit that heat treated and galvanized bridge wire will break under combined bending and tension stresses (such as exist at anchorage shoes and under suspender clamps) and breaks because of some trouble inherent in all the wire rather than in isolated spots, the trouble is not due to slow changes in the microstructure which supposedly weaken and embrittle it.



Homo Furnace tempering small quantities of parts to within ± 1-½ points Rockwell at extremely low cost

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